ANALYSIS OF TECHNICAL EFFICIENCY OF SMALLHOLDER TEFF PRODUCTION: THE CASE OF LEGEHIDA WOREDA, SOUTH WOLLO AMHARA, NATIONAL REGIONAL STATE, ETHIOPIA

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YIMER ARAGAW

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ANALYSIS OF TECHNICAL EFFICIENCY OF SMALL HOLDER TEFF PRODUCTION: THE CASE OF LEGEHIDA WOREDA, SOUTH WOLLO AMHARA, NATIONAL REGIONAL STATE, ETHIOPIA

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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Agricultural Economics

Yimer Aragaw

Major Advisor: Abebe Dagnew (Assistant.Prof)

Co-Advisor: Yemane Michael (PhD candidate)

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APPROVAL SHEET OF THE THESIS

SCHOOL OF GRADUATE STUDIES

GONDAR UNIVERSITY

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Abebe Dagnew(Assistant Prof.) _______________ ____________

Major Advisor Signature Date

Yemane Mechael (PhD candidate) __________________ ____________

Co-Advisor Signature Date

As member of the Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by Yimer Aragaw and examined the candidate. We recommend that the thesis be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Agricultural Economics.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the Council of Graduate Studies (CGS) through the Departmental Graduate Committee (DGC) of the candidate's major department.

DEDICATION

I dedicate this thesis manuscript to the whole members of my family especially to my mother Merema Beshir and my father Aragaw Hassen.

STATEMENT OF THE AUTHOR

First, I declare that this thesis is my real work that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirement for an advanced MSc degree at the Gondar University and is deposited at the University Library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHICAL SKETCH

The author was born on February 16, 1993 in Kire Gebeya rural Kebele administration, in Legehida Woreda of South Wollo Zone, Amhara National Regional State. He attended his elementary school at Gola(1-4) and Kire Dembiya(5-8) elementary school in Legehida Woreda from 2001to 2008. He attended his secondary school at Woreilu General secondary and Preparatory School in Woreilu Woreda, South Wollo from 2009 to 2012.

After successful completion of his high school education, he joined Addis Ababa University in October 2013 and graduated with Bachelor of Sciences Degree in Agricultural Economics in July 2015. He joined the Post Graduate program of Gondar University to attend his post graduate study in Agricultural Economics in September 2016.

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ACRONYMS AND ABBREVATIONS

ACSI	Amhara Credit and Saving Institution
ATA	Agricultural Transformation Agency
CSA	Central Statistical Agency
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
KA	Kebele Administration
LR	Likelihood Ratio
LWGCAO	Legehida Woreda Government Communication Affairs Office
MDE	Man Day Equivalent
ML	Maximum Likelihood
MLE	Maximum Likelihood Estimation
MoFED	Ministry of Finance and Economic Development
OLS	Ordinal Least Square
SE	Standard Error
SNNPR	Southern Nations, Nationalities and Peoples' Region
SPA	Stochastic Production Analysis
SPF	Stochastic Production Frontier
STD	Standard Division
TE	Technical Efficiency
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor

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ABSTRACT

Production and productivity can be boosted either through increased use of inputs or by improving the efficiency of producers. The opportunities to increase farm production by bringing additional physical resource into cultivation have been diminishing. Then, reducing the existing inefficiency among farmers can be more effective. A Cobb-Douglas stochastic frontier production analysis approach with the inefficiency effect model was used to simultaneously estimate TE and to identify source of difference in TE among farmers in Legehida woreda. This study considers the effect of agro-ecological zone on the TE of production which is other researchers gave little attention. The study employed a multi stage sampling technique to select a representative sample of 119 households based on cross-sectional data. Farmers on average attained 59.5, 63 and 52 percent of TE level in the study area as the whole, midland and lowland areas, respectively. This is an indication that there is an opportunity to increase teff production by about 40.5, 37 and 48 percent in the study area as the whole, midland and lowland areas, *respectively. The test result also shows that 54, 56 and 95 percent of deviation of teff output from the frontier is attributed to technical inefficiency of the farmers in the study area as the whole, midland and lowland areas, respectively. The ML estimates showed that oxen power and labor positively and significantly influenced teff output while amount of seed influenced teff output negatively and significantly in the study area as the whole. All input variables were found to be significance in lowland area whereas labor, DAP and oxen were found to be significant in midland area. The estimated inefficiency factors model shows that education, age, livestock holding, farm size and meeting are significant in the study area as the whole. The positive coefficient of farm size and meeting indicate that as the size of farm and time of meeting increase, TE will decrease while the negative coefficient of education, age and livestock holding indicates that improvement in these factors results in a significant increase in level of TE in the study area as the whole. Meeting and farm size affect TE negatively while education affect TE positively in midland area. Credit and fragmentation affect TE positively and negatively lowland sample farmers respectively. As a recommendation, emphasis should be given to improve the efficiency level of those less efficient farmers in the study area as the whole, midland and lowland area by focusing on the above mentioned significant input and inefficiency variables.*

***Key words**: technical efficiency, teff production, lowland and midland, Legehida woreda*

1. INTRODUCTION

In this chapter, background of the study, statement of the problem, objective of the study, significance of the study, scope and limitation of the study and organization of the study have been presented.

1.1. Background of the Study

Though agriculture remains to be the most important sector of the Ethiopian economy, its performance has been disappointing and food production has been lagging behind population growth (Knife *et al.*, 2012). This gap between demand for and supply of food can be reduced by using two ways. The first method is through introduction of modern technologies. The other option of improving productivity is to enhance the efficiency of producers with a given level of inputs and technology (Beyan *et al.*, 2013).This study is mainly concerned on increasing productivity through enhancing the technical efficiency of smallholder farmers.

The Ethiopian Government aims to double agricultural production in, the 2010/11-2014/15. However, this target is challenged by specific sectoral and systemic constraints which require new approaches to overcome (Alemayehu *et al.*, 2011).

Agricultural production level and productivity vary place to place. Agricultural environmental production conditions such as rainfall and temperature have their own impact on production efficiency. The knowledge of how climatic factors affect production efficiency and how efficiency varies across different agro-ecologies can assist policy in choosing agricultural technologies that are more adaptable to specific agro-ecologies and enhance sustainable development of the agricultural sector in the face of climate factors. The study implies that climatic factors do affect production efficiency as these factors influence the amounts of inputs used in production (Alem *et al.*, 2010).

The major crops are grown in the diverse agro-ecological zones including conditions marginal to the production of most other crops in Ethiopia. Even though there are areas where the crops are grown during the short rainy season (Belg), Teff is mainly cultivated during the main rainy season (Meher). The length of growing period ranges from 60 to 180 days (depending on the variety and altitude) with an optimum of 90 to 130 days. It can also grow in low rainfall and drought prone areas characterized by protracted growing seasons and frequent terminal moisture stress. The cultivation of Teff in Ethiopia has partly been motivated by its relative merits over other cereals in the use of both the grain and straw (Teklu Tedase, 2010).

In Ethiopia, teff is mainly produced in Amhara and Oromia Regions, with smaller quantities in Tigray and SNNPR Regions. There are 20 major teff producing zones in the country. In Amhara Region, East Gojjam, West Gojjam, North Gonder, South Gonder, North Wollo, South Wollo, North Showa and Awi zones are the major producers of teff. In Oromia Region the major teff producing zones include East Showa, West Shoa, South West Shoa, North Shoa, Oromia Special Zone Surrounding Finfine, East Wellaga, Horo Guduro Wellaga, Jimma, Illubabor and Arsi Zones. The Central and South Tigray Zones are the major teff producing zones in Tigray (ATA, 2011).

The study area is endowed with three agro-ecological zones. However, teff is produced only in lowland and midland agro-ecological zones. Teff production varies across agro-ecological zone due to marvelous variation in farming systems, population density, and socio-economic conditions in the different agro-ecological zones. In the study area teff production is relatively low in lowland areas due to the fact that lowland areas are poverty stricken areas that make farmers unable to purchase modern agricultural input on time. Lowland areas are mountainous area with poor transportation facilities, poor market access and institutions, a lot of bare hills and small parcels of land with low productivity (Bamlaku *et al*., 2009).

Teff is the second most widely produced and consumed cereal in Ethiopia. Teff has remained an important crop to Ethiopian farmers for several reasons, namely: the price for its grain and straw are higher than other major cereals; the crop performs better than other cereals under moisture stress and waterlogged conditions; its grain can be stored for a long period of time without being attacked by weevils (Solomon Bizuayehu, 2014). However, its output is relatively low (around 1.4 ton per hectare) and high loss rates (25-30 percent both before and after harvest) decrease the quantity of grain available to consumers by up to 50 percent (CSA, 2014). This holds true for the region in which this study is undertaken. Teff is the most widely adapted crop compared to any other cereal or pulse crop in the study area and is grown under wider agro-ecologies (variable rainfall, temperature and soil conditions). In fact, several studies have been conducted to analyze technical efficiency performance of farmers in Ethiopia. However, there is a tremendous technical efficiency variation across agro-ecological zone, which are somehow neglected in these studies. Therefore, in this study the effect of agro-ecological zone on technical efficiency of teff was taken into account.

1.2. Statement of the Problem

In developing country like, Ethiopia agricultural production and productivity is low and the agricultural output growth imbalance with population growth. In Ethiopia there are high potential areas which can produce enough grains to meet the needs of the deficit areas' people. However, lack of efficiency in agricultural systems demotivates farmers to produce more (Knife *et al.*, 2012).

In the study woreda, farmers have access to improved varieties of cereals. Modern technologies are promoted by development agents. On-farm trials and demonstration of improved crops production packages (improved varieties and management practices) have been conducted in the woreda to promote adoption of the technology. However, agricultural technology utilization and shocking weather condition are the major factors remained to be crucial for the low production and productivity of agriculture (Mohammed Ereshid, 2012). This is an indication that farmers are not using improved varieties and modern technologies efficiently.

Teff play a major role to carry out agricultural policy decisions as a prime staple food for food security reasons and for the overall development of the agricultural sector and the economy. Output can enhance by increasing the area devoted to crops or by introducing new technology. However, if the existing production system is not efficient, introduction of new technology cannot bring the expected improvements in the productivity of teff production. The opportunities to increase farm production by bringing additional forest land into cultivation or by increasing the utilization of the physical resources have been diminishing. In addition, eliminating existing inefficiency among farmers can prove to be more effective than introducing new technologies as a means of increasing agricultural output and farm household income (Wondimu Tesfaye, 2013).

Ethiopia is endowed with a variety of agro-ecological zones, which differ in terms of rainfall patterns, temperature conditions, soil types, altitude and other physical landscapes. The reason is that there is tremendous variation in farming systems, population density, and socio-economic conditions in the different agro-ecological zones. For instance, in the highlands, there is limited farmland, but population pressure mounts. On the other hand, in kola areas (lowlands) there is very erratic rainfall, high poverty and severe resource degradation (Bamlaku *et al*., 2009).

Legehida Woreda is divided into three agro-ecological zones, namely lowland, midland and highland zones. However, teff is produced only in lowland and midland. Heterogeneity of teff production is not only depending on physical resource and available technology but also environmental production condition such as rainfall and temperature across agro-ecological zones. Poor transportation facilities, poor market access, low input utilization and a lot of bare hills with low productivity are common in lowland area than midland area (Juma, 2013). This indicates that there is efficiency variation across agro-ecological zones i.e. (midland to lowland).

Different researches have been conducted on efficiency of production in Ethiopia including (Hassen Beshir, 2016; Hailemaraim Leggesse, 2015; Mohammed *et al*., 2010; Asefa Solomon, 2012 and Teffera *et al*., 2014) etc. However, none of those researchers did consider the effect of agro-ecological zone on the technical efficiency of production. Since technical efficiency may vary from lowland to midland, it is better to collect data from both altitudes in order to ensure representativeness of data. The study is intended to fill this gap. This study tried to answer the following leading research questions:

1. What is the existing mean technical efficiency of teff producing farmers in the study area?
2. What are the factors that cause efficiency variations of teff production in Legehida woreda?

1.3. Objectives of the Study

The general objective of this study is to analysis the technical efficiency of smallholder teff production in Legehida Woreda.

The specific objectives of the study are:

1. To measure the level of technical efficiency in the production of teff in the study area
2. To identify the sources of differences in technical efficiency among the farmers in the study area.

1.4. Significances of the Study

This study provides an understanding of teff production potential areas, and analysis the difference in technical efficiency in production activities. It will play a significant role in providing useful information concerning technical efficiencies in production and by identifying those factors, which will be associated with inefficiencies that may exist. It will also provide whether there is technical efficiency variation across agro-ecological zone or not. If there is variation, it will be identified the factors that cause this variation. It will also indicate an entry point for further policy interventions to technical efficiency of smallholder farmers. Therefore, this study is expected to generate adequate understanding of the issues that might lead towards taking appropriate actions for improvement of efficiencies.

Moreover, it will help developmental agents of the area to come with some important idea of efficient utilization of available production inputs for those who are inefficient. This information will also help farmers to make appropriate decisions, so as to increase their production. The document will also serve as a reference for researchers to embark on similar or related work in other parts of the country.

1.5. Scope and Limitations of the Study

The area coverage is limited to Legehida woreda. Farmers in the study area produce many types of crops. Cereals are the dominant crops from the known food grains in the study area. Therefore, this study focuses on teff production only. If the study includes majority of the kebele administrations, it would have been more representative. However, the study is limited to three kebele administrations, out of 12 kebele administrations found in the lowland and midland part of the woreda, and 119 respondents due to limited resources, such as finance and time. Moreover, the results of cross sectional data did not show the change over time that was important for a follow up development strategy.

1.6. Organization of the Study

The rest of the thesis organized in to the following. The second chapter discussed review of literature covering definitions of some important terms, approaches of measuring efficiency such as input oriented measure and output oriented measure, determinants of technical efficiency, empirical efficiency Studies in different countries and in Ethiopia and includes review on efficiency models. In the third chapter, the profile of the study area, sampling technique, the method of data collection and analysis, description statistics and econometric analysis and definition of the study variables were discussed. The fourth chapter concerned with results and discussions. It includes the results of description statistics and econometric analysis. The summary, conclusions and policy implications are presented in the last chapter.

2. LITERATURE REVIEW

In this chapter, conceptual and theoretical technical efficiency and empirical studies made on efficiency in different countries and in Ethiopia have been reviewed.

2.1. Concept of Technical Efficiency

Technical efficiency is a component of productive efficiency and is derived from the production function. Productive efficiency consists of technical efficiency and allocative or factor price efficiency. Allocative (or price) efficiency refers to the ability to combine inputs and outputs in optimal proportions in the light of prevailing prices, and is measured in terms of behavioral goal of the production unit like, for example, observed vs optimum cost or observed profit vs optimum profit. Technical efficiency is measured as the ratio between the observed output and the maximum output, under the assumption of fixed input, or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output (Porcelli, 2009).

Production frontier characterizes the minimum input bundles required to produce a given level of output or the maximum possible level of production of output from a given level of inputs, commonly called technical efficiency. Even though there is some similarity between terms production efficiency and technical efficiency, however, they are not same. The simplest way to differentiate production and technical efficiency is to think of productive efficiency in terms of cost minimization by adjusting the mix of inputs*,* whereas TE is output maximization from a given mix of inputs (Palmer and Torgerson, 1999). Technical efficiency which explains the physical performance of a firm) measures the relative ability of a farmer to get the maximum possible output at a given input or set of inputs. Technical efficiency of a producer is a comparison between observed and optimal values of its outputs and inputs. It refers to the ability to avoid wastage either by producing as much output as technology and input usage allow or by using as little input as required by technology and output production.

Technically efficient farmers are those farmers that are operating on the production frontier that represents the maximum output attainable from each input level. Technical inefficiency can be defined as the quantity by which a firm lies below its production frontier or profit frontier. The firm is more inefficient, when it is more distant from the frontier (Farrell, 1957).

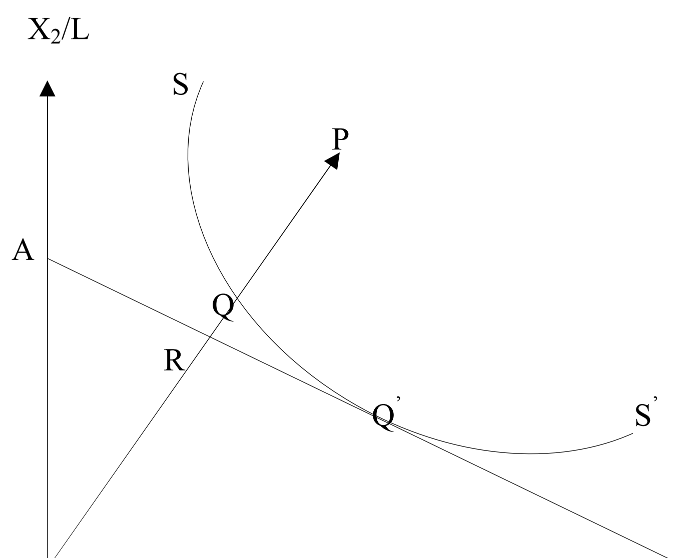
2.2. Approaches of Measuring Efficiency

There are two approaches to the measurement of technical efficiency: output-oriented approach and input-oriented approach. In the output-oriented approach the concern lies on to what extent that output could be increased at a given level of inputs. Whereas in the second approach the interest is the amount by which inputs could be minimized to achieve technically efficient level of production (Murillo-Zamorano, 2004). These approaches are sometimes referred as output-short fall and input-overuse, respectively.

2.2.1. Input oriented measure

In his first work on efficiency, Farrell (1957) illustrated his idea about measuring efficiency with figure, as follow. The SS' is an iso-quant, representing technically efficient combinations of inputs, X_1 and X_2, used in producing output Q. SS' is also known as the best practice production frontier. AA' is an iso-cost line, which shows all combinations of inputs X_1 and X_2 to be used in such a way that the total cost of inputs is equal at all points. However, any firm intending to maximize profits has to produce at Q', which is a point of tangency and representing the least cost combination of X_1 and X_2 in production of Q. At point Q' the producer is economically efficient.

Figure 1: Input oriented measures of technical efficiency



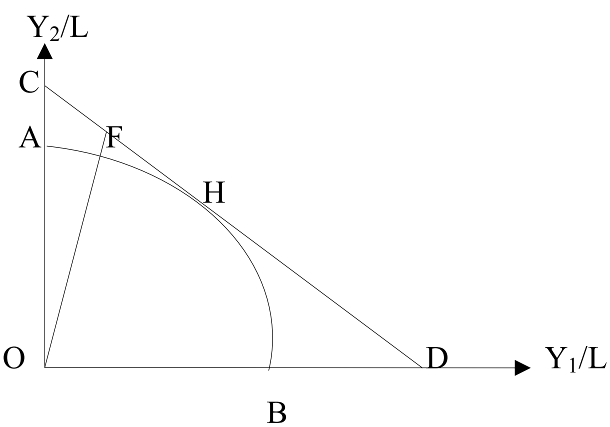
Source: Coelli, 1995

Given figure 1, suppose a farmer is producing his output depicted by iso-quant SS' with input combination level of (X_1 and X_2). Production at input combination at point P is not technically efficient because the level of inputs needed to produce the same quantity is Q on iso-quant SS'. In other words, the farmer can produce at any point on SS' with fewer inputs (X_1 and X_2), in this case at Q in an input-input space. The degree of technical efficiency of such a farm is measured as $\frac{OQ}{OP}$ which is proportional in all inputs that could theoretically be achieved without reducing the output. Hence all farmers that produce along the iso-quant are 100 percent technically efficient.

2.2.2. Output oriented measure

In the output oriented perspective, efficiency is estimated keeping inputs constant. According to Farrell (1957), output oriented measures can be explained by considering the case where production involves two outputs (Y_1 and Y_2) and a single input (L). If the input quantity is held constant at a particular level, the technology can be symbolized by a production possibility curve in two dimensions as follows.

Figure 2: Output oriented measures for technical efficiency



Source: Coelli, 1995

The production possibility curve is represented by the curve AB in Figure 2, which represents technically efficient combinations of production of outputs Y_1/L and Y_2/L. Given same level of input (L), it is not efficient to produce at point Q by considering a firm situated at point Q, the technical efficiency can be calculated as OQ/OG. Alternatively, all farmers producing along the production possibility curve are 100 percent technically efficient.

2.3. Models for measuring efficiency

In frontier models, technical efficiency is measured based on the performance of an individual producer compared to the most efficient producer in the industry. Various approaches have been used to measure efficiency of a producer. The most commonly used approaches are the econometric (parametric) approach, and the mathematical (non-parametric) approach. The parametric models are estimated based on econometric methods and the non-parametric methods of measuring productive inefficiency are broadly speaking dependent upon categorization of quantitative and qualitative variables under the famous methodology of Data Envelopment Analysis (Burhan *et al.*, 2009). In this study econometric (parametric) approach was used. Efficiency measures assume as production function of the fully efficient firm is known. But this is not true in the reality; hence the efficient iso-quant must be estimated from the sample respondent taking the comparatively best performing firms as fully efficient (Coelli *et al*., 2006). Parametric approach is used in this study; the current literatures on parametric frontier models briefly as follows.

There are two types of parametric frontier model. These are deterministic and Stochastic Frontier Production (SFP) model. The main difference between the two models is on their assumption about the error term. The deterministic model supposes that any deviation from the frontier is due to inefficiency, while the stochastic approach allows for statistical noise.

2.3.1. Non- stochastic/deterministic

The first parametric deterministic frontier production function was estimated by Aigner and Chu (1968) assuming a Cobb Douglas functional form. The deterministic frontier model for cross-sectional data is defined as,

$$Y_i = F(X_{ij};\ \beta) - u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1) \qquad (\, i = 1, 2 \ldots\ldots\ldots\ldots n)$$

Where Y_i =is the output of the i^{th} firm;

X_i= is the vector of input quantities used by the i^{th} firm;

β = is a vector of unknown parameters to be estimated;

$F(.)$ = denotes an appropriate function u_i = a non-negative variable representing the inefficiency in production

This method still sacrifices the analysis of random errors which is possible occurred particularly in agricultural production. Deterministic estimates would, therefore, be estimated to be lower or higher than those from the SPF. The random errors may affect the deterministic output positively or negatively. So that, whether stochastic or deterministic output yield higher or lower estimates cannot be determined a priori. Moreover, theoretical as well as empirical findings revealed that estimating efficiency using this method approach is the same as efficiency estimation using SFA during in availability or smaller random errors beyond control of the farmer. More importantly, in a recent meta-analysis of the factors influencing technical efficiency estimates in developing country agriculture, a study by Thiam *et al*. (2001) found that stochastic frontier models did not generate significantly different technical efficiency indices than deterministic models.

However, agricultural production in developing countries especially in Ethiopia is likely influenced by risks like natural hazards, climatic condition and measurement errors. Given these, none of the above techniques are being really used in current study. Rather, it is preferred to focus on an alternative econometrical approach which has become the most popular and widely used parametric approach for the measurement of economic efficiency, namely stochastic frontier model (Coelli *et al*., 2006).

2.3.2. Stochastic frontier production function

To solve the weakness of deterministic approach of Aigner and Chu (1968); Timmer (1971) designed a method that involves dropping a percentage of farmers neighboring to the estimated frontier, and re-estimating the frontier using the reduced sample. The arbitrary nature of the selection of some percentage of observation to omit has meant, however, that Timmer's probabilistic approach has not been widely followed (Coelli, 1995). In the process of managing the outliers, so that the inefficiency level would not be exaggerated, farmers who outperform will be considered as outliers. Assume that there are i observations of farmers indexed as $\mathrm{i} = 1 \ldots \ldots . \mathrm{I}$ who use a vector of $\mathrm{x} > 0$ inputs, which are indexed as $\mathrm{x} = 1 \ldots \ldots \mathrm{xN}$ to produce $y > 0$ outputs.

Following Kumbhakar and Lovell (2000), the stochastic frontier production function can be specified as:

$$Y_i = f(X_i\,;\beta)\exp(V_i - U_i) \dots\dots\dots\dots\dots\dots\dots\dots.. \;(2) \qquad\qquad i = 1, 2, \dots\dots..n$$

Where,$f(X_i;\beta)$ and $\exp\,(V_i - U_i)$ represent the deterministic and stochastic part of the production frontier respectively. β is a vector of parameters to be estimated, where as V_i is the symmetric error component, which is assumed to be independently and identically distributed as $N(0, \sigma^2)$. It accounts for the random variations in output due to factors outside the control of the farmer such as weather, disease, measurement error etc. On the other hand, u represents the technical inefficiency relative to the stochastic frontier and assumes only positive values (Neff *et al.*, 1993). Its distribution is assumed to be half normal being identically and independently distributed as $N(0, \sigma^2)$.

Let $\sigma^2 v$ and $\sigma^2 u$ be the variances of the parameters symmetric (v) and one-sided (u) error terms. It then follows that,

$$\sigma^2 = \sigma^2 v + \sigma^2 u \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (3)$$

And the ratio of the two standard errors as used by (Jondrow *et al.,* 1982):

$$\lambda = \sigma v + \sigma u \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

According to Battese and Corra (1977), the variance ratio parameter γ which relates the variability of u_i to total variability (σ^2) can be calculated in the following manner;

$$\gamma = \lambda^2(1 + \lambda^2) \text{or } \gamma = \frac{\sigma^2 u}{\sigma^2 v + \sigma^2 u} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

So that $0 \le \gamma \le 1$. This means that if the value of γ equals zero, the difference between yields (outputs) of farms is entirely due to statistical noise. On the other hand, a value of one would indicate that the difference is attributed to technical inefficiency (Battese and Corra, 1977; Coelli, 1995).

Following Aigner *et al*. (1977) and Kumbhakar and Lovell (2000), the stochastic frontier production function in equation (1) above can be specified as:

$y_i = f(x_i; \beta) \exp(v_i). TE \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$

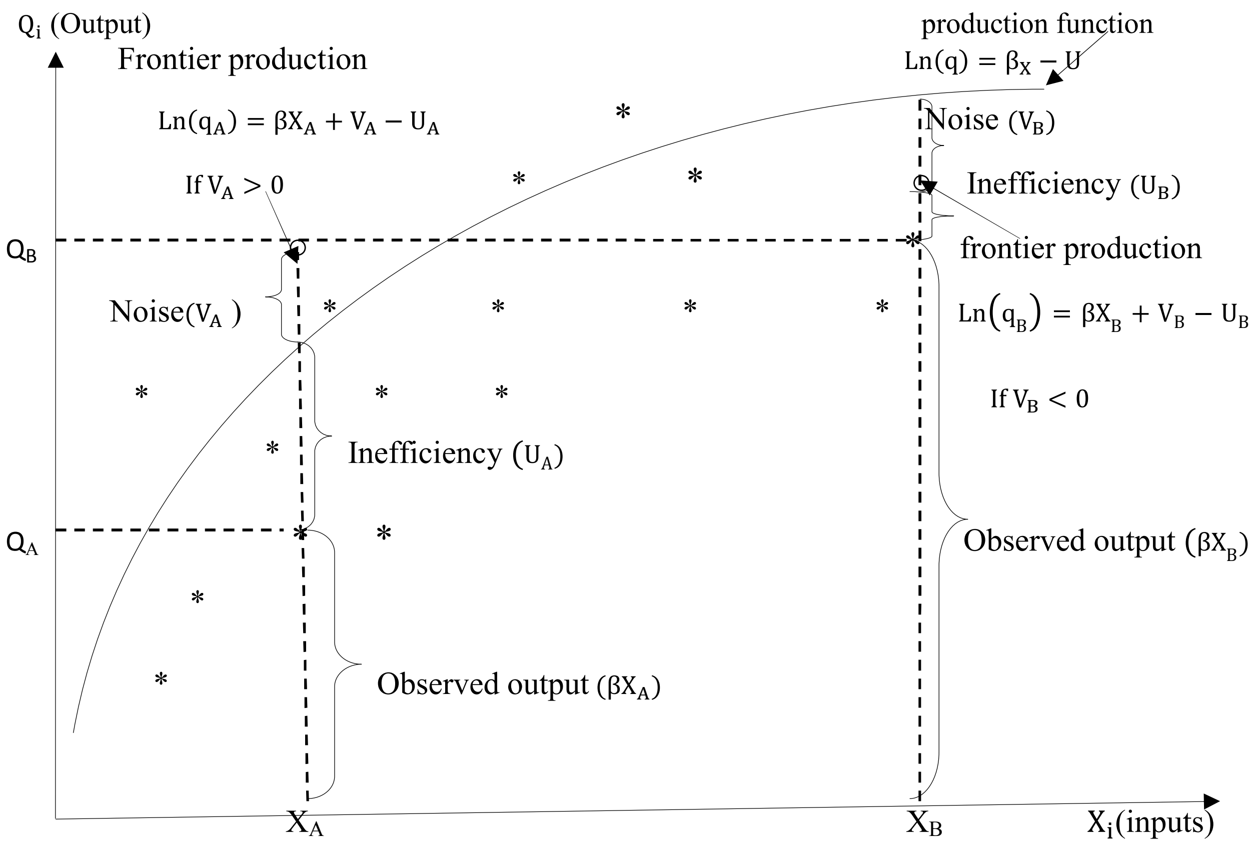
After dividing both sides by $f(x_i; \beta) \exp(v_i)$ we can rewrite equation (6) as follows:

$$TE_i = \frac{y_i}{f(x_i; \beta) \exp(v_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$U_i = Z_i\, \delta + W_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Z_i is a vector of explanatory variables associated with the technical inefficiency effects, and δ is a vector of unknown parameters to be estimated, and W_i represents unobservable random variables, which are assumed to be identically distributed. They are obtained by truncation of the normal distribution with mean zero and unknown variance σ^2, such that u_i is non-negative. TE refers to the technical efficiency of the i^{th} farm, y_i is the observed output, $f(x_i; \beta)$ indicate the deterministic part that is common to all producers, exp $\{v_i\}$ is a producer specific part, which captures the effect of random noise on each producer. From equation (7), we can observe that technical efficiency is the ratio of observed output to maximum feasible output in an environment characterized by exp $\{v_i\}$.

Figure 3: Graphical representation of stochastic frontier production function



Source: (Neumann *et al*., 2010)

2.2. Empirical Literature Review

2.2.1. Empirical technical efficiency studies in the world

In this subchapter of the literature, recent studies done on TE in different parts of the world are reviewed. Most of the studies done in the area of TE, focus on the TE of single crop production. This study also focuses on single crop teff production.

Dawit *et al*. (2012) conducted a study on innovation systems and technical efficiency in developing-country agriculture using a stochastic frontier analysis of production functions to estimate the level of technical efficiency in agriculture for a panel of 29 developing countries in Africa and Asia between 1994 and 2000. The result showed that the mean level of technical efficiency among the sampled countries was about 86 percent, with some modest increases during the period in question. Their result suggested that there is room for significant increases of production through reallocations of existing resources. Despite significant variation among countries, these result also indicate quite a number of least developed countries have high mean 18 efficiency scores, implying a need to focus on investment that pushes the production frontier outward in these countries. Several measures of agricultural research and development achievement and intensity, along with educational enrollment, are found to enhance agricultural efficiency. On the other hand, countries with higher levels of official development assistance, foreign direct investment, and a greater share of land under irrigation are found to be performing poorly in their agricultural efficiency score.

Isaac (2011) used a cross sectional data and estimated the level of technical efficiency of maize producing-farmers in Oyo State, Nigeria and further examined the factors that determined the differential in efficiency index. Stochastic frontier production model was used in the analysis to determine the relationship between the maize output and the level of input used in the study area. The farm size and seed where found to influence efficiency of maize production positively and significantly. Hence, the study confirmed that more land could still be brought for maize production in the area with the existing level of input use.

Abdi *et al*. (2012) analyzed the technical efficiency in wheat production in the rain-fed cropping zone of Punjab through Cobb Douglas stochastic production frontier. Based on the cross sectional data, collected from a random sample of seventy farm households. The mean technical efficiency of wheat production in the study area was found to be 47.1 percent. The result signified that farmers of the rain-fed zone of Punjab have a scope to increase productivity of wheat through technical efficiency improvements under the existing conditions of input-use and technology. Seed rate has contributed negatively and significantly to wheat production, indicating that there is a possibility to increase wheat production by decreasing seed rate. Irrigation application to the crop has significant positive contribution to wheat production indicating that there is scope for increasing wheat production by improvement in moisture availability through better conservation of rain water or investment in water sources. The inefficiency in wheat production was due to sowing of poor quality seed year after year and large operational farm size in Rabi season

A study done by Abba (2012) on the technical efficiency of sorghum production and its determinants used stochastic frontier production function which incorporates a model of inefficiency effects. He used farm level data collected from a sample of 100 sorghum farmers in Hong local government area of Adamawa state, Nigeria. According to his study, land, seed, and fertilizer were the major factors that influence changes in sorghum output and education, extension contact and household size were major explanatory variables that had significant effects on the technical inefficiency among the sorghum producers. The TE of farmers varied from 15.62 to 92.14 percent with a mean TE of 72.62 percent. The implication of the study is that efficiency in sorghum production among the farmers could be increased by about 27 percent through better use of land, seed and fertilizer in the short term given the prevailing state of technology. In his study, Abba (2012) recommended policy interventions by the government in terms of better access to land, improved seed and fertilizer.

Beckhman *et al*. (2010) estimates a quadratic stochastic frontier production function to examine the determinants of technical efficiency in rice farming in Bangladesh. The analysis of the determinants of technical efficiency revealed that the age and education of the household heads, availability of off-farm incomes, land fragmentation, extension visits, were the major factors that caused efficiency differentials among the farm households studied. Hence, the study proposed strategies such as providing better extension services and farmer training programs, reducing land fragmentation and raising educational level of the farmers to enhance technical efficiency.

Dlamini *et al*. (2010) used farm-level cross-sectional data for estimating source of technical efficiency from 40 sugarcane schemes and 35 individual sugarcane farmers in Switzerland. The sugarcane farmers at Vuvulane over-utilized land. Thus, an appropriate amount of land utilization could increase the sugarcane production for Vuvulane sugarcane farmers. For both groups of farmers, the technical inefficiency decreased with increased farm size, education and age of the sugarcane farmer, but increased when small scale sugarcane farmers engaged in off-farm income earning activities.

Addai and Owusu (2014) conducted a study on technical efficiency of maize farmers across various agro-ecological zones of Ghana. The result showed that the mean technical efficiency of maize producers in the forest, transitional and savannah zones are 79.9 percent, 60.5 percent and 52.3 percent, respectively. This indicated that there is technical efficiency variation across agro-ecological zones. The results reveal that extension; mono cropping, gender, age, land ownership and access to credit positively influence technical efficiency. High input price, inadequate capital and irregularity of rainfall are the most pressing problems facing maize producers in the forest, transitional and savannah zones, respectively. The study therefore recommends that policies that would improve extension service, education and development of crop varieties suitable to the different agro-ecological zones should be pursued.

2.2.1. Empirical efficiency studies in Ethiopia

Hailemaraim Leggesse (2015) undertook a study on technical efficiency in teff production in Bereh Woreda, in Oromia. The Cobb-Douglas production function was used to estimate the efficiency of teff producers in the area. The study showed teff output was positively and significantly influenced by area, fertilizer, labor and number of oxen. This would mean that there is a room to increase teff output from the existing level if farmers are able to use these input variables in an efficient manner. The result further showed that there were differences in technical efficiency among teff producers of the area. The estimated mean level of technical efficiency of teff producers was about 72 percent. This reveals that there exists a possibility to increase the level of teff output by about 28 percent through exploiting the existing local practices and technical knowledge of the relatively efficient farmers. Fertility status of the farm, off-farm occupation, education and extension contact were found to determine technical efficiency significantly.

Teffera *et al*. (2014) analyzed the technical efficiency in teff production in the Raya Alamata woreda through Cobb Douglas stochastic production frontier. The result signified that farmers of the Raya Alamata have a scope to increase productivity of teff through technical efficiency improvements under the existing conditions of input-use and technology. The yield of teff can be improved through adoption of better practices of technology. Fertilizer application rate has contributed positively and significantly to teff production, indicating that there is a possibility to increase teff production by increasing fertilizer application rate. Education of the household has significant positive contribution to teff production indicating that there is room for increasing teff production by improvement the education level of the farmers. The inefficiency in teff production was due to sowing of poor quality seed year after year and large operational farm size.

Essa *et al.* (2011) assessed farm-level resource use efficiency in the production of teff*,* wheat and chickpea using a cross sectional data obtained from 700 rural households in the central highland of Ethiopia. The data envelopment analysis results showed that smallholder farmers were resource use inefficient and the regression results on the determinants of inefficiency revealed that livestock ownership and participation in off-farm activities were significantly associated with reduced level of resource use inefficiency. It was also found that those households whose decision makers have roles in their community activities show improve resource use efficiency. The study also suggested that resource use efficiency would be significantly improved through a better integrated livestock and crop production systems; off farm activities and integrating community leadership in various community activities and programs. Moreover, market infrastructure development would likely increase efficiency and agricultural productivity.

Beyan *et al*. (2013) Analyzed of Farm Households' Technical Efficiency in Production of Smallholder Farmers in Girawa through Cobb Douglas stochastic production frontier. The results from the production function showed that fertilizer, inorganic, labor, oxen power and seed were statistically significant. The result also confirmed that technical efficiency of farmers is positively associated with education, extension services and livestock holdings. Thus, education and extension services increases efficiency of a farmer by increasing awareness and ability on the proper use of farm inputs control of pest and crop diseases and overall management of farm productions. Livestock enhances efficiency directly through their use in farming operation; and indirectly by financing farm income in bad production years. Similarly, Asefa Solomon (2012) also confirmed the importance of education and extension services in improving technical efficiency of farmers in the study on Ethiopian smallholder farmers.

Solomon Bizuayehu (2014) used the SPF model together with the inefficiency parameters to identify factors affecting level of technical efficiency of crops show that age of the household head measured in years was found to be the determinant of technical inefficiency, negatively and significantly. Alternatively, age has a positive and significant effect on TE of teff production. However, teff has enormous potential for growth as it has been given very little attention in research, development and public support. The crop is the second most widely produced and consumed cereal in Ethiopia. Teff has remained an important crop to Ethiopian farmers for several reasons, namely: the price for its grain and straw are higher than other major cereals; the crop performs better than other cereals under moisture stress and waterlogged conditions; its grain can be stored for a long period of time without being attacked by weevils.

Getahun Gemechu (2014) undertook a study on off-farm income and technical efficiency of smallholder farmers in Ethiopia. The study used a stochastic frontier model in the derivation of individual efficiency scores and estimation of factors determining technical efficiency in smallholder farming. The Cobb-Douglas form of the production function was found to be more appropriate in representing the data than the translog. The estimation results show that size of farm land, household size, off-farm income and education of the household head are the most significant variables determining the value of farm output. The average technical efficiency of farmers is only 53 percent, implying the existence of wider scope for improvement of their efficiency. In addition, maximum likelihood estimation result indicates that household size, education of the head, extension services and off-farm income are major factors for differences in technical efficiency among farmers.

Endrias *et al.* (2013) by applying DEA model that the average technical efficiency of maize production Wolaita and Gamo Gofa zones of Southern Nations, Nationalities and Peoples Region of Ethiopia was found to be about 0.40. This investigates that if the average farmer in the sample was to achieve the technical efficiency level of its most efficient counter-part, then the average farmer could realize 60 percent cost savings. This indicates that there was a substantial amount of technical inefficiency in maize production. However, about 7.26 percent of the DMUs operated at greater than 90 percent technical efficiency level in maize production and they also investigated by applying tobit model to show that farm size and oxen holding were highly significant at affecting the technical efficiency of smallholder maize producers.

Abebayehu Girma (2011) undertook a study on the technical efficiency of haricot bean seed production in Boricha woreda of Sidama zone, southern Ethiopia. It was based on cross sectional data collected from 120 haricot bean seed multiplying farmers during 2010/11 production season. The Cobb-Douglas production function was used to estimate the efficiency of haricot bean seed producers in the area. He revealed from the estimated SPF model that, area of the plot, DAP fertilizer, seed, oxen and amount of pre-harvest labor were significant determinants of production level. The results further indicated that there was inefficiency in the production of haricot bean seed in the study area and the relative deviation from the frontier due to inefficiency is 74 percent. The estimated Cobb-Douglas SPF with inefficiency variables showed that the mean TE of farmers in the production of haricot bean seed was 69.5 percent. His result implied that education, livestock holding, and membership in seed multiplying cooperative were important factors in determining the existing efficiency of farmers.

Mohammed *et al*. (2010) measured technical efficiency of barely production in Asasa woreda of southeastern Ethiopia. They estimated both level and determinants of efficiency differential among farmers in a one-stage estimation procedure by fitting translog stochastic production function. The study revealed that farmers in the area were only producing on average 55 percent of their maximum possible output level, given the state of technology at their disposal. Of the eleven variables included in the inefficiency model, livestock holding, contact with extension, inherent fertility status of the field, weed management and rotation were found significant to determine inefficiency. Coefficients of livestock holding and rotation practice representing fallow/pulse was negative indicating complimentary effect of livestock on barely production and plots that followed pulse or fallow were more efficient than plots which followed linseed. Besides, coefficients of contact with extension, inherent fertility status of the field and weed management were found positive which is beyond expectations made.

Wondimu Tesfaye (2013) undertook a study on determinants of technical efficiency in maize production of smallholder farmers in Dhidhessa Woreda, Illubabor zone, Ethiopia. The Stochastic Production Frontier (SPF) result revealed that area allocated under maize and chemical fertilizers appeared to be significantly influencing maize production. The average technical efficiency was 86 percent while return to scale was 0.96 percent. Based on the results, it was concluded that there existed scope for increasing maize output by 14 percent through efficient use of existing resources. Hence if the experience and knowledge of farm household heads that attained higher technical efficiency were shared among other farmers in the woreda, an additional output of 2060 quintals of maize could have been produced given 7550 hectares of land allocated to maize production during the study period in the woreda. Thus, ample scope existed to realize higher maize output with existing resources and level of production technology. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, improved seed, training on maize production and labor availability in the household.

Hassen Beshir (2016) measured the level of technical efficiency and identifies its determinants in wheat crop for smallholder farmers in South Wollo Zone, Ethiopia. The Stochastic Production Frontier (SPF) result revealed that area allocated under wheat, seed, fertilizer applied and labor in man-days were appeared to be significantly influencing wheat production at less than 1 percent probability level. The average technical efficiency was 78 percent while return to scale was 1.17 percent implying that farmers are operating at an increasing return to scale. The socio-economic variables that exercised important role for variations in technical efficiency were age, education, farm size, and livestock holding in Tropical Livestock Unit and number of oxen holding. Nevertheless, participation on off farm income was found to decrease efficiency significantly among farm household. This indicates that there is a room to increase technical efficiency of farm households.

A study conducted by Abebe Dagnew (2009) on technical efficiency of smallholder onion producers in Kalu Woreda in South Wollo Zone of Amhara Regional State based on the cross sectional data collected from 158 selected farmers and used a Cobb-Douglas stochastic production frontier model. The result shows that urea, seed, area and expenditure on pesticide were found to affect onion output positively. The estimated mean technical efficiency of the sample households was about 77 percent. This shows that there exists a possibility to increase the level of onion output by about 23 percent through exploiting the existing resources of the sample households. Slope, irrigation cooperative membership and family size were found to affect negatively while extension contact and training affect the level of technical efficiency positively.

A study by Bamlaku *et al*. (2009) on technical efficiency factors across agro-ecological zones in East Gojjam was identified some efficiency variables like age and sex of household head, educational level of household head, membership status of household in organizations, participation in off-farm activities, labor endowment, proximity to the market, livestock ownership and family size-farm size ratio. Besides the identification of the sources of inefficiency variables the maximum likelihood estimates of their finding indicated positive and significant elasticity for inputs such as land, labor, draft power and fertilizer. Whereas education, proximity to markets, and access to credit were found to reduce inefficiency levels significantly. But extension visits and trainings on farmland management affects the efficiency level of farmers positively. Again, agro-ecological differences of the smallholder farmers significantly show the persistence of technical efficiency variation among them. Thus, future development endeavors may need to find ways to envisage better development intervention programs that are tailored to the peculiarities of the agro-ecological zones.

The above empirical studies which were employed in different parts of Ethiopia in different agro-climatic and socio-economic conditions indicated the existence of efficiency differentials among smallholder farmers. Moreover, these studies also showed that there is a considerable variation of factors of inefficiency which are responsible for efficiency differentials. Though production efficiency of different crops has been investigated in Ethiopia, production efficiency of teff in the study area has not been covered as far as the knowledge of the author of thesis goes.

3. RESEARCH METHODOLOGY

In this chapter, description of the study area, sampling technique, source of data and methods of data collection, method of data analysis and definition and measurement of study variables have been presented.

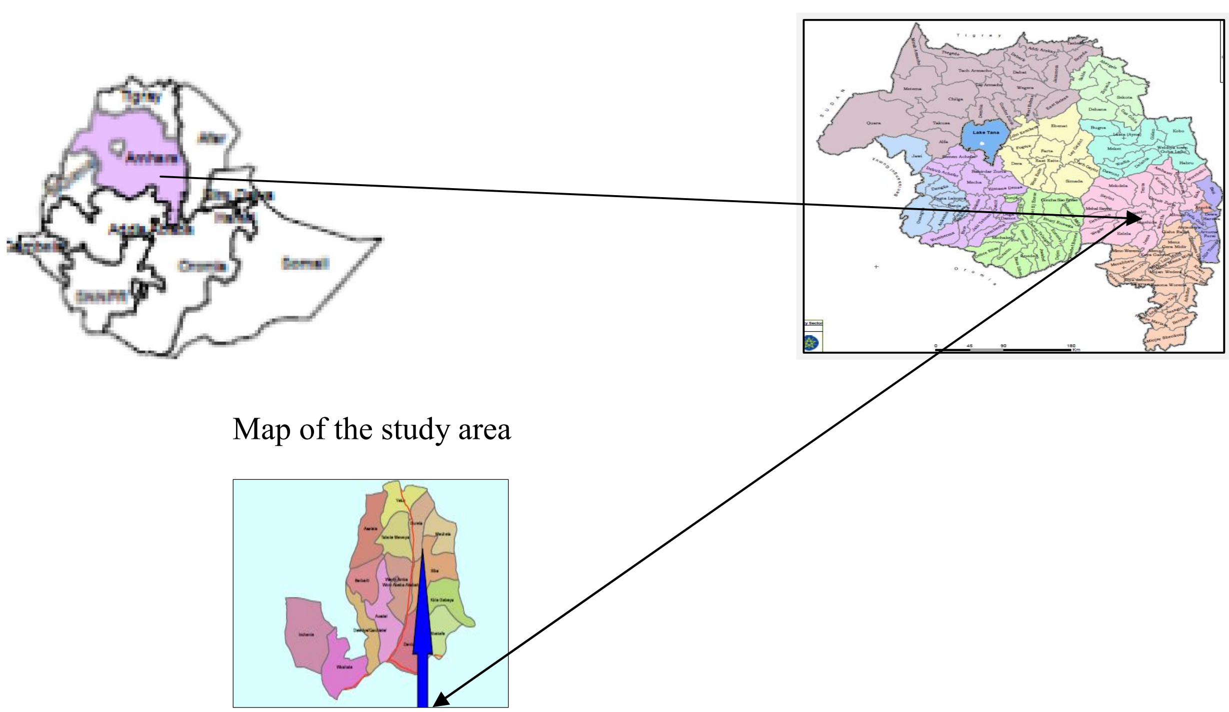
3.1. Description of the Study Area

The study area is located in the South Wollo of the Amhara National Regional State of Ethiopia. Legehida Woreda is found around 104 kilometer south-west of Dessie, the capital of South Wollo, 578 kilometer from Bahirdar towards east and 540 kilometer towards north from Addis Ababa. The Woreda is bordered by Jama Woreda in the South, Kelala Woreda in the west, Legameo Woreda in the North and Woreillu Woreda in the east. According to Legehida Woreda Government Communication Affairs Office bulletin (2011), the total land area of the Woreda is 42935 hectare. Legehida Woreda has 15 (4 lowland, 8 midland and 3 highland) kebele administrations. The topography of the Woreda is rugged and mountainous. From the total land area of the Woreda 36.23 percent is mountainous, 17.38 percent is rugged and 42.69 percent is flat land. The Woreda has 19.8 percent lowland (kola), 55.5 percent midland (Woyna dega) and 25.7 percent highland (dega) agro-ecological zones. The Woreda has an annual rain fall of 990-1400 mm/year and the temperature ranges from 17-25c° (LWGCAO, 2011). The rainfall distribution pattern is Uni-modal commencing towards end of May and ending in October.

The major crops grown in the area are cereals such as teff, wheat, maize, sorghum and barley, pulses: bean, pea, chickpea and lentil. Fruits and vegetables are also grown in the Woreda. The Woreda is the major producer of wheat, teff, sorghum, barely, fruits and vegetables; while pulse crops are the major cash crops. The soil type is mainly black clay and red. Teff is one of the major annual crops grown in the Woreda. Teff grows in both 'red and black' soil types. Application of manure, compost, crop rotation, fallowing, plant residue and chemical fertilizers are methods of maintaining soil fertility in the Woreda. Teff in red soil types is sown in July while teff sown on black clay soil commonly sown late, in the end of the rainy season at residual moisture in black soil types to overcome the problem of water logging (LWGCAO, 2011).

In addition to crop production, livestock production is also common in the area. Livestock production in the area is the source of draft animal power for plowing and threshing, source of income next to crop production, and it serves as a risk minimization strategy during crop failure and as one source of fuel. From animal production stand point, the Woreda had 37581 cattle, 67246 sheep and goats, 109111 non ruminants, 33195 poultry and 3618 hives of which 765 with modern beehives (LWGCAO, 2011). According to the Census of 2007 E.C., the population of the Woreda is 78,225 persons of which 96 percent are rural households with an average household size of 5 persons. Based on Legehida Woreda Agriculture and Development Office, the total number of households in the study area is 15,642, and the total number of households in the selected 04 (Kachilet), 010 (Kire) and 012 (Siba) kebele administrations is 861, 1249 and 1212, respectively.

Figure 4: Map of the study area



Source: Mohammed Ereshid, 2012

3.2. Sampling Techniques

This study was used multistage sampling to draw a representative sample. In the first stage, by using stratifying sampling, the woreda is stratified into lowland and midland based on agro-ecological zone. In the Woreda teff is produced only lowland and midland area. Since, there is difference in teff production between lowland and midland using stratifying sampling is appropriate in the study area. In the second stage, since producers in each stratum are homogenous by using random sampling techniques two kebele administrations were selected from 8 midland kebele administrations and 1 kebele administration from 4 lowland kebele administrations. In the third stage, a total number of 119 sample farmers were randomly selected from 3 kebele administrations. The total sample size was distributed to each sampling unit based on the probability proportional to size sampling technique. The sample size was determined by using the formula given by Yamane (1967) that is:

$$n = \frac{\mathrm{N}}{1 + \mathrm{N}(e^2)} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (9)$$

N= 3322 then $n = \frac{3322}{1+3322(0.09)(0.09)} = 119.03311 = 119$

Where, n is sample size, N is the total number of households in the selected kebele administrations and e is the desired level of precision i.e. taking e as 9 percent and N as 3322

Table 1: Total number of households of the KAs and number of sample farmers from each KA

Agro-ecology	Kebele administration	Total teff producers sample farmers	Sample size
Lowland	Kachilet	861	31
Midland	Kire	1249	45
	Siba	1212	43
Total	Three	3322	119

Source: Legehida Woreda Agriculture and Development Office

3.3. Source of Data and Methods of Data Collection

Both primary and secondary sources of data were used in generating the required data. The data set contained detailed information on households' demographic characteristics, farm characteristics, input utilization, output produced and institutional related variables.

The primary data was collected from randomly selected sample farmers from the selected kebele administrations. Data collection was done using a semi structured interview schedule. A semi structured interview schedule includes land coverage of teff, the amount of output obtained from teff plots, fertilizers and oxen power usage, amount of seed, and total labor used in performing different farming activities in the production of teff.

Experienced enumerators were recruited and trained to facilitate the task of data collection. The enumerators were given a brief explanation and training on how to gather information according to the interview schedule before they embarked on data collection. There was continuous supervision during data collection. Individual interviews with key informants from farmers, development agents, concerned agricultural professionals and administration offices at all levels were also conducted.

The secondary data was obtained from studies conducted and information documented at various levels of Central Statistical Agency, Agriculture and Development Offices in the study area. Important literatures on technical efficiency were also assessed from the internet.

3.4. Methods of Data Analysis

Both descriptive and econometric methods of data analysis were employed. Descriptive statistics such as mean, standard deviation, percentage and frequencies were used to analyze the socio-economic characteristics of teff production of the sample farmers while inferential statistics such as t-test and chi-square(X^2) tests were used to undertake statistical tests on different continuous and categorical data, respectively..

3.4.1. Descriptive analysis

This method was used to summarize and analyze the sample farmer input use, output levels and their socio-economic characteristics, used in the frontier production and in the efficiency model respectively.

3.4.2. Econometric analysis

3.4.2.1. Specification of the empirical econometric model

The SPF model in general production function for the i^{th} farmer's Teff production is given by:

$$Y_i = f(X_{ij}; \beta) + \varepsilon_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (10)$$

Where:

Y_i= a scalar output of the i^{th} farmer;

X_{ij} = a vector of actual input variables used by the i^{th} farmer/farm;

β = a vector of production coefficients to be estimated;

ε_i = is a composed error term$(V_i - U_i)$;

V_i =Random variability in the production that cannot be influenced by the farmer;

U_i =deviation from maximum potential output attributable to technical in/efficiency relative to the stochastic frontier which is given by $f(X_{ij}; \beta) + V_i$ and assumes only positive values.

3.4.2.2. Selection of the functional form

Following the Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) stochastic frontier production function was estimated with a Cobb-Douglas production functional type of specification. The Cobb-Douglas functional model was specified as follow to estimate the technical in/efficiency level in teff production of smallholder farmers in the study area.

$$\ln Y_i = \ln \beta o + \Sigma \beta_j \ln X_{ij} + V_i - U_i \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots (11)$$

Where: Ln = the natural logarithm (i.e., to base e)

Y_i is teff output in quintal from the i^{th} farmer

X_1 is area which was covered with teff in hectare by the i^{th} farmer

X_2 is total amount of seed sown in teff plot in kilogram

X_3 is labour input used in man-days by the i^{th} farmer

X_4 is the quantity of urea input applied by the i^{th} farmer in kilogram

X_5 is the quantity of DAP input applied by the i^{th} farmer in kilogram

X_6 is oxen inputs used by the i^{th} farmer in pair of oxen-days

β_0 is the level of teff output from an hectare of land at natural state (the intercept) and

β_j' s the other constitutes a vector of parameters to be estimated

v_i is a symmetric error term accounting for the deviation from the frontier because of factors which are beyond the control of the farmer (such as variation in weather, measurement error and other statistical noise) and

u_i, is a one sided error term accounting for the deviation because of efficiency effects. $v's$ are independently and identically distributed normal random variables with zero means and variances, i.e. $v_i \sim dN(0, \sigma^2)$ and $u_i's$ are non-negative/one sided random variable $(u \geq 0)$ efficiency component that captures/measures the deviation from the maximum potential output that are attributable to technical inefficiencies in teff production, which is represented and given by the stochastic frontier output $f(X_{ij} ; \beta) + v_i$.

3.5. Definition and Measurement of Study Variables

The following variables that were used both in the production function and in the inefficiency model were selected based on the reviewed literatures, theoretical and/ or empirical justification, teff production characteristics and socio-economic condition of the study area. All inputs and outputs were transformed to their corresponding log values in estimating the Cobb Douglas production function.

3.5.1. Production variables

These variables include both the output (dependent) and inputs which are the independent factors of production, used in the production process of teff.

The dependent variable

Teff Output: Teff output is described in terms of physical quantities. The output is made by local units such as sack of urea, sack of DAP, and"*Kunna*" and then converted into standard unit, quintal.

The independent variables and their hypothesis

Area: Refers to total area of plot used for production of teff during the production year by each sample farmer. This variable is included in the model by converting the area measured in local unit in to standard unit, hectare. The finding of Hailemaraim Leggesse (2015) shows that direct relationship between area of teff plot and level of production. Then, it was expected to increase technical efficiency of teff production.

Urea: Refers to the total amount of urea applied by the i^{th} farmer on teff field in the study area. This variable was included in the model by converting the urea measured in local unit into standard unit, kilogram. The finding of Abebe Dagnew (2009) shows that urea increase the level of production. Then, it was hypothesized to increase technical efficiency of teff production.

DAP: Refers to the total amount of DAP used by the sample farmers on teff field. This variable was included in the model by converting the DAP measured in local unit into standard unit, kilogram. The finding of Abebayehu Girma (2011) shows that a positive relationship between DAP and level of production. Then, it was expected to increase technical efficiency of teff production.

Oxen power: The total number of oxen days used by sample farmer head for performing different farming activities of plowing and measured in pair of oxen-days. Then it is included in the production frontier model. The finding of Bamlaku *et al*. (2009) shows that a positive relationship between oxen power and level of production. Then, it was expected to increase technical efficiency of teff production.

Labor: Labor is an important input for agricultural production. Labor force utilization of sampled farmers on teff plot was recorded during the survey. The record was done by the type of person participated on the given activity by categorizing as children, men and women. Thus, labor inputs for major activities were converted into pre-harvesting man-day equivalent. It was hypothesized that the available labor is related positively to technical efficiency. Given the fact that the labor is the main input in crop production, a farmer that had more labor in the household could carry out important crop husbandry practices timely (Hasssen Beshir, 2011). Then, it was expected to increase technical efficiency of teff production.

Seed: This refers to the amount of teff sowed on teff plot by the sample farmer. It is included in production function frontier in physical quantity, by converting the local unit into standard unit, kilogram. The effect of this variable on the level of technical efficiency of teff production can be ambiguous that means it may be positive or negative. On the one hand, Isaac (2011) using stochastic frontier production model found that seed influence the level of production positively and significantly. Hence, the study confirmed that more land could still be brought for production in the area with the existing level of input use. On the other hand, Abdi *et al*. (2012) using stochastic frontier production model found that seed affect the level of production negatively and significantly. The reason is that usage of higher seed rate decrease the level of production.

3.5.2. Inefficiency variables

Meeting: The total number of hours or days the household waste in kebele administration or local meeting by development agents, kebele administration leaders or community leaders in a week or a month in the peak production season. It reduces the supply of labor in the farm activities. It also prolongs farming activities beyond the intended period. Then, it was expected to reduce technical efficiency of teff.

Fertility of teff plot: The fertility status of the soil defined as a dummy that would take a value 1 if the plot is fertile and 0 if not. Farmers asked to categorize their plot as fertile or infertile land as they know the fertility status of their land approximately. A farmer who tried to maintain the fertility of his/her land or farmers endowed with fertile land were more efficient than those infertile lands (Mohammed *et al*., 2010).

Off-farm occupation: It is a dummy variable which have the value of one if the farmer or his economically active family members are engaged in any off-farm employment; zero otherwise. The effect of this variable on technical efficiency of teff can be ambiguous that means it may be positive or negative. While on the one hand, Essa *et al.* (2011) by using SPF model found that off-farm activities supplement the agricultural activities in terms of providing cash income there by purchase necessary inputs timely. On the other hand, Wondimu Tesfaye (2013) argued that farmers who participated in off-farm work were likely to be less efficient in farming as they share their time between farming and other income-generating activities.

Family size: It is a continuous variable and is aggregated by employing man-day equivalent. This is done by first categorizing members of the household into children, men and women and according to sex. Mekde Aberas (2011) found that increase in household size increases expenditure for home consumption; therefore, it determines production negatively by creating financial stagnation in order to give immediate response for demands of agricultural inputs. This result is contradicted with those households with larger family size are more efficient; indicating their higher possibilities of having larger labor supply during peak agricultural seasons (Getahun Gemechu, 2014). The effect of this variable is ambiguous. Then, it was hypothesized that negative or positive effect on technical efficiency of teff.

Education: Education of the household head is a continuous variable and measured in years of formal schooling. This is used as a proxy variable for managerial ability of the decision making unit (household head). It is assumed that through education the quality of labor is improved and he/she become active to adopt new technologies. It is more likely that farmers with higher educational status have better perceptive to grasp agricultural expert advice (Dlamini *et al*., 2010). It was expected to affect technical efficiency positively.

Age: It is measured as age of the household head in years. Empirical studies for example Addai and Owusu (2014) argue that older households are more experienced than younger ones. On the other hand, older household heads are more reluctant to adopt new technologies which increase their level of inefficiency than the younger one (Bekele Alemayehu, 2013). Based on these ground, the effect of this variable on technical efficiency is ambiguous. Therefore, in this study age was hypothesized to affect technical efficiency of teff producers positively or negatively.

Farm size: This is a continuous variable which represents the total crop area in hectares managed by a farmer. This variable is considered to see the character of efficiency level as a result of difference in land holding among smallholder farmers. The effect of this variable is ambiguous. Endrias *et al*. (2013) found using Tobit model that as the farm size of a farmer increases, the managing ability of a farmer will decrease given the level of technology. This finding contradicted with that there is a positive relationship between farm size and small-scale teff producers` technical efficiency that means as farm size increase farmers give more attention to carry out farming activities efficiently (Tefera *et al*., 2014). Therefore, in this study farm size was hypothesized to affect technical efficiency of teff producers positively or negatively.

Livestock holding: This is a continuous variable and is approximated by Tropical Livestock Unit (TLU). The effect of this variable on technical efficiency of teff can be ambiguous that means it may be positive or negative. While on the one hand, Beyan *et al*. (2013) found that possession of large number of livestock indicated greater wealth and capacity. Livestock in a mixed farming system had many contributions for farm household. It supplied oxen power for plowing, sources of food and income for the family. Then, livestock holding allow farmers to make the necessary input available on time at the required amount. On the other hand, Hassen Beshir (2016) argued that the sample farmers who held large number of livestock reallocated much of their time in herding livestock and hence less time for crop management. Due to this fact, farmers who owned large livestock might be less technical efficient as compared to those who possessed large livestock.

Slope: Slope is taken as a dummy variable, where 0 indicates that the land is steep and 1 otherwise in accordance with farmer's evaluation. Relatively steep land reduces the output level of teff production because steep land is susceptible for water erosion problem. Slopes of plot were found to be related negatively to technical efficiency (Abebe Dagnew, 2009). Based on this, it was hypothesized that farmers who sow teff on steep land are less efficient than those with gentle or plan slope.

Credit: This is a dummy variable that represents the use of any forms of credit associated with crop production by farmers. If the farmer has taken credit, the variable takes a value of 1 and 0 otherwise. The availability of credit for resource poor farmer is important to finance the agricultural activities (Adil and Hanan, 2015). Therefore, it was hypothesized that farmers who have used credit are expected to be more efficient than others.

Fragmentation: It is the total number of plots of all (owned, rented and shared) land operated by sample farmer. A larger number of plots may decrease inefficiency of a farmer if the farmer has enough man power to manage the farm activities. However, increasing number of plots operated by a single farmer may increase level of inefficiency. This is due to the fact that it would become less effective and less accessible to manage each plot if they are large in number and scattered (Beckhman *et al*., 2010). So, it was hypothesized that the more the number of plots a given household operates, the more inefficient the farmer would be.

Time of sowing: Sowing time is a dummy variable where 1 indicates late sowing and 0, otherwise. Early sowing starts from mid-end of June and late sowing is to mean sowing which occurred in the beginning of September. Earlier sowing fevers moisture but growth may stagnate due to water logging problem. Late sowing minimizes the problem of water logging that constrains teff production on vertisols. Late sowing time is preferred on a relatively gentle areas and vertisols. Early sowing is preferred on sandy soil and on relatively sloppy areas where water logging problem does not occur. However, about 75 percent of the study district is covered with vertisols. Hence, it was hypothesized that farmers who sow teff late are more efficient.

Topography of teff plot: It is a dummy variable where 1 indicates midland and 0 indicate lowland. Production varies across agro-ecological zone. It was hypothesized that technical efficiency is low in lowland than midland. The reason is that since lowland areas are poverty stricken areas. The lack of resources to timely prepare their fields, apply inputs in time (as they are far from markets and institutions), and manage their land intensively (Bamlaku *et al*., 2009).

Table 2: Expected sign of variables on technical efficiency

	Input variables	Type	Expected sign
1	Area	Continuous	+
2	Urea	Continuous	+
3	DAP	Continuous	+
4	Oxen power	Continuous	+
5	Labor	Continuous	+
6	Seed	Continuous	-/+
	Inefficiency variable		
1	Meeting	Continuous	_
2	Education	Continuous	+
3	Fertility status of the farm	Dummy	+
4	Off farm occupation	Dummy	-/+
5	Slope	Dummy	_
6	Credit	Dummy	+
7	Age	Continuous	-/+
8	Livestock holding	Continuous	-/+
9	Family size	Continuous	-/+
10	Farm size	Continuous	-/+
11	Time of sowing	Dummy	_
12	Land fragmentation	Continuous	_
13	Topography	Dummy	_

Source: Own computation

4. RESULTS AND DISSCUSSION

This chapter is divided into two main sections: descriptive statistics and econometric results. Results on descriptive analysis in which survey data were used to describe the socio-economic factors of sample farmers are discussed in the first section. In the second section, econometric results were discussed.

4.1. Socio-economic factors of Sample farmers

4.1.1. Demographic and household characteristics

Age

Age is one of the important factors which determine management experience of farmers. So it is plausible to discuss age structure of farmers within the sample. The survey result shows that, the age of most farmers i.e. about 72.3 percent is below 50 years and 27.7 percent of the household heads were found at the age greater than 50 years. Mean age of household heads is 43.47 years with in the range of 23 and 80. Most households of the sample farmers (92.4 percent) are male headed. Among the sample farmers considered, about 85.7 percent of them are married, 2.5 percent are non married, 2.5 percent widowed and 9.5 percent of them are divorced.

Table 3: Age group and sex of sample farmer heads in the production year (2015/2016)

Variables	Age group (years)		Total
	<50 (in percent)	>50 (in percent)	
Male	67.23	25.21	82.44
Female	5.04	2.52	7.56
Total	72.27	27.73	100

Source: Survey result, 2017

Age of the sample farmer also has implication on farm economy and agricultural productivity. Because availability of work force and other socio-economic factors in the agricultural society might be determined by age of the household. The survey result on age of the sample farmer shows that about 72.27 percent of the sample farmers were categorized as economically active groups whereas 27.73 percent of the sample farmers were above the age of 50.

Household size

Total number of individuals and their composition within household determine availability of labor power needed in farm production. In the study area, the average household size was 5.31, with a minimum of 1 and a maximum of 11. This average household size is very large as compared to average adult equivalency of 3.2. This indicates that there is highest dependency ratio.

Table 4: Age structure of household members of the sample farmers

Age category	Percent
<10	14.76
10-13	10.475
14-16	13.50
17-50	50.475
>50	10.79
Total	100

Source: Survey result, 2017

Most Sample farmers belonged to Muslim religion (93.3 percent) and the remaining 6.7 percent of the sample farmers were followers of Orthodox Christianity.

Education

Education improves managerial skills and an intention to adopt new technologies. Educated farmer is also willing to employ experimentation on his/her plots. The education level of the farm society has implication on agricultural production. In the study area, the average year of schooling of the household heads were found to be 3.7 years. From the total household heads, about 8.5 percent were illiterate and about 32 percent of the sample farmer farmers were able to read and write due to adult illiteracy eradication campaign undertaken within the last few years. About 51.3 percent of them have attended elementary school education and about 8.2 percent of them have attended high school education.

Table 5: Educational status of sample farmer

Education level	Percent
Illiterate	8.5
read and write due to adult illiteracy eradication campaign	32
Elementary school	51.3
High school	8.2
Total	100

Source: Survey result, 2017

4.1.2. Farm characteristics

Land is the main factors of production. The average land holding of the sample farmers in the study area is almost 1.9 hectare with standard error of 0.87.The minimum and maximum size of land holding was 0.5 hectare and 4 hectare, respectively. As shown in Table 6 about 36.1 percent of sample farmers are land less than 1.5 hectare, about 56.3 percent of sample farmers had 1.5 to 3 hectare of land and about 7.6 percent respondent farmers had greater than 3 hectare.

Table 6: Distribution of the sample farmers by land size

Land holding (hectare)	Number	Percent
<1.5	43	36.1
1.5-3	67	56.3
>3	9	7.6
Total	119	100

Source: Survey result, 2017

Land exchange in informal markets is a common practice in the area. Farmers rent-in land or share others land when they get enough money to cover all input expenses and the renting price. On the other hand, farmers rent-out their land when they face financial problems to meet social or other obligations or engaged in other nonfarm activities. During the survey year, about 11 percent of the sample farmers have shared land and 12.6 percent of the sample farmers rented-in land.

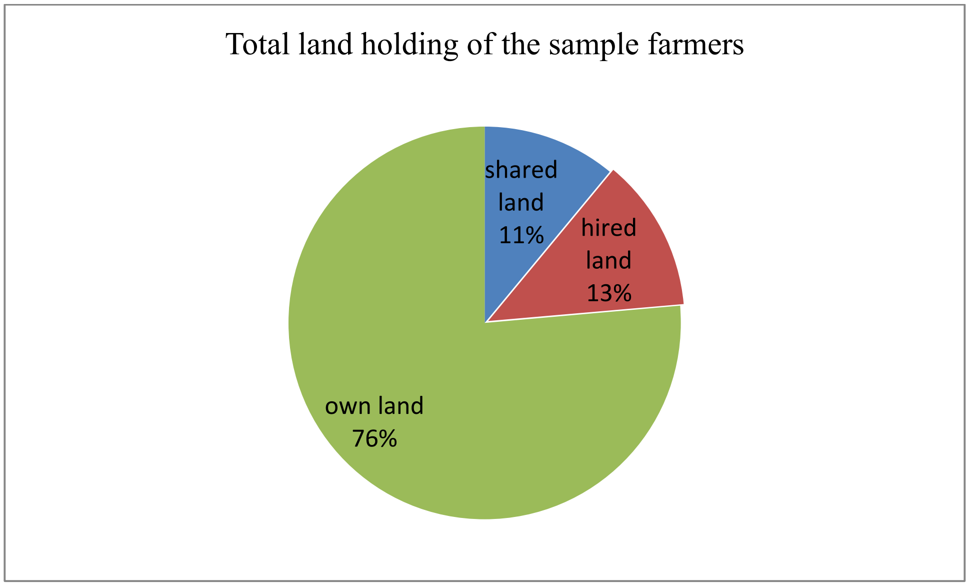
Table 7: Extent of informal land exchange practices in the study area

Land exchange	Number	Percent
Hired land	15	12.6
Shared land	13	11
Total	28	23.6

Source: Survey result, 2017

As figure 5 shows that the sample farmers were used 76, 11 and 13 percent of owned land, shared land and hired land from the total land holding in the study area, respectively.

Figure 5: Land ownership under different ownership types of sample farmers



Source: Survey result, 2017

The cultivated area was divided into several plots. The number of plots ranged from 1 to 8 with average and standard deviation of 3.34 plots and 1.60, respectively. As the table 8 indicated that, about 35.3 percent of the sample farmers in the study area owned cultivated land with the range of 1 to 2 plots. About 40.5 and 24.4 percent of the sample farmers owned cultivated land with the range of 3 to 4 and above 4 plots, respectively.

Table 8: The general distribution of the plot of land was summarized as follow.

Number of plots	Number of household head	Percent
1 and 2	42	35.3
3 and 4	48	40.3
Above 4	29	24.4
Total	119	100

Source: Survey result, 2017

4.1.3. Factors of production

Labor

Human labor required for management and production of crops and animals is supplied almost entirely by members of the household. About 93.09 percent of labor force required for teff production was provided by members of the household. Farmers also deploy hired laborer at an average wage rate of 40-50 Ethiopia birr per day during peak season of agricultural production. There is also other type of labor resource management like labor exchange arrangements especially during seasons where there is shortage of labor. Exchange and hired labor and cover about 5.22 and 1.69 percent of the labor use in the production of teff, respectively.

Table 9: Labor use for teff production in the production year of 2015/2016

Types of labor (MDE)	Number	Mean	STD
Total labor	2895	24.33	10.85
Family labor	2695	22.65	10.27
Hired labor	49	0.41	1.87
Exchange labor	151	1.27	3.67

Source: Survey result, 2017

Farmers used on average 24.33 man-days per hectare for all agricultural activities in producing teff with a range of 3.78 to 56.85 man-days per hectare. Oxen were the only sources of traction power in the area. Shortage of draught power limits the area that can be cultivated. Shortage of oxen power leads to poor land preparation and delayed completion of the operation. Poor land preparation leads to poor plant establishment, heavy weed infestation and low yields. Oxen power utilization by sample farmers was computed by assuming working of 8 hours by pair of oxen per day. The sample farmers utilized oxen power with a range of 2 to 28.50 pair of oxen per day. Average oxen power used by the sample farmers was 8.93 oxen days per ha with standard deviation of 5.50.

Fertilizer

All the sample smallholder farmers used both urea and DAP chemical fertilizer. About 31.09 percent of sample farmers used compost and manure organic fertilizer (i.e.19.33 percent and 11.76 percent, respectively).

Table 10: Fertilizer utilization of sample farmer

Types of fertilizer	Mean	Sta .Dev
Amount of urea	46.83	21.69
Amount of DAP	53.78	29.14
Amount of compost	8.71	2.04

Source: Survey result, 2017

As table 10 shows that the sample farmers on average used 46.83 and 53.78 kilogram per hectare of urea and DAP fertilizer with the standard deviation of 21.69 and 29.14 kilogram per hectare, respectively. On average the sample farmers used 8.71 kilogram per hectare of compost with the standard deviation of 2.04 kilogram per hectare in the study area.

Seed

Farmers are not obliged to use a certain amount of kilogram of seeds per hectare. Any amount of seeds can be used. However, the extension department in the study area recommends 8-12 kilogram per hectare seed rate for teff depending on many considerations such as fertility of the land, type of the variety, degree of weed problem. The survey result shows that the sample farmers on average used seed at a rate of 20.78 kilogram per hectare. This result shows that the farmers used excess seed rate above the recommended amount in the study area. As seed rate increase the growth and development of teff plant become stunted and teff yield become low.

Most small-scale farmers who practice subsistence farming do not buy certified seeds, but they use recycled seeds that are stored after every harvest, while others buy recycled seeds from their fellow farmers. This practice affects the crop output every year in terms of quantity as well as quality.

4.1.4. Major crops grown

A mixed crop-livestock farming system is practiced in the Legehida Woreda. The cropping system is dominated by teff and wheat production. Teff production is used mainly for home consumption and commercial purpose and it is a dominant crop produced in the study area. Most farmers have more than one plot so that they sow two or more than two crops during the production year. In terms of the proportion of land coverage, teff ranks first (68.9 percent) followed by wheat (16 percent), lentil (6.7 percent), sorghum (5.9 percent) and others (2.5 percent). All of the sampled farmers produce teff in the production year of 2015/2016.

Table 11: Major crops sown by sample farmers based on area coverage in study area

Major crop	Number of respondent	Percent	Rank
Teff	82	68.9	1st
Wheat	19	16	2nd
Lentil	8	6.7	3rd
Sorghum	7	5.9	4th
Others	3	2.5	5th
Total	119	100	

Source: Survey result, 2017

Teff was produced in a sloppy area and gentle area. Almost 54.6 percent of the sample farmers produced teff in a gentle area, and about 45.4 percent of the sample farmer produced teff in a sloppy area. Among the sample respondents 54.6 percent of farmers produced teff in low fertility plot and 45.4 percent of farmers produced teff in high fertility plot.

Teff was also sown early or lately based on the types of soil and the preference of the farmers in the study area. About 51.3 percent of sample farmers sowed teff early, and about 48.7 percent of sample farmers sowed teff lately.

4.1.5. Off-farm activities

Farmers in the study area are engaged in various off-farm activities in parallel with the main farming activities during the farming season. Some of these activities are; grinding mills, handicraft, and selling of local drinks. The income they desperately need to obtain from such off-farm activities may substantiate the low income that is usually obtained from farming activities.

Table 12: Off-farm occupation condition of sample farmers in 2015/2016 production year

Off-farm activity condition of farmers	Number	Percent
Sample farmers engaged in off-farm activities	24	20.2
Sample farmers not engaged in off-farm activities	95	79.8
Total	119	100

Source: Survey result, 2017

As table 12 shows that, slightly above 20 percent of the sample farmers participated at least in off-farm activities while nearly 80 percent of the sample farmer did not participate in off–farm activities.

4.1.6. Institutional service

Credit

Agricultural credit facilities are vital in productive resources mobilization through purchase of agricultural inputs, availing resources for meeting social obligations, etc. Formal and informal institutions were the two main sources of credit in the study area. The major sources of informal credit were friends, relatives and neighbors.

Table 13: Credit used by the sampled farm household

Credit	Number	Percent
Credit user	47	39.5
Non credit user	72	60.5
Total	119	100

Source: Survey result, 2017

According to the survey result, it has been seen that some smallholder farmers were used credit services for production of teff. The major formal credit providing institution in the study area was Amhara Saving and Credit Institution (ASCI). Loan from local lenders, family/friends, NGOs constitute the informal credit sources, which usually needs no interest on loan. As far as the access to credit is concerned, about 60.5 percent of sample farmers reported that they did not obtain credit from credit providing institution whereas, the remaining 39.5 percent of sample producers were received credit from ASCI.

Meeting

The total number of hours the household wasted in kebele administration or local area in the peak production season. It reduces the supply of labor force in the farm activities. As table 13 shows that, on average, each sample farmer spent 12.29 hour with the range of 1 to 34 hour. This indicates that on average the sample farmer spent more than 1.5 man-days in a week. This hour was very expensive for farmers in peak agricultural production.

Table 14: Total number of hour the sample farmer spent in meeting in a week

Total hour in spent (MND)	Number of household	Percent	
< 1	37	31.1	
1-2	45	37.8	
>2 and <3	23	19.3	
≥3	14	11.8	
Total	119	100	
Mean	Maximum	Minimum	Sta .Dev
12.29	34	1	7.76

Source: Survey result, 2017

As the table 13 shows that, 31.1 percent of the sample respondent spent less than 1 man-day in meeting per week. About 37.8 and 19.3 percent of the sample farmers spent with the range of 1 to 2 and (2 to 3 inclusive) man-day in meeting per week, respectively. About 11.8 percent of the sample farmer spent their gold time greater than and equal to 3 man-day per week. Those sample farmers had societal responsibility in the kebele administration or local area.

4.1.7. Livestock production

In the study area, livestock production is source of cash next to crop production. Farmers sell poultry and ruminants in order to fulfill their immediate cash demand and rear them for home consumption. They use horses and donkeys for transportation and ox is merely their source of draught power. Animal dung is used to maintain fertility of land, as energy source for cooking and as a source of income.

As table 15 shows about 14.3 percent of the sample farmers have no ox, while 37 percent of sample farmers have a single ox and 36.1 percent of sample farmers have a pair of oxen. About 12.6 percent of sample farmers have 3 to 5 oxen. Those farmers owning 3 or more oxen, lease-in land or share-cropping for more production, also they rent oxen power for other farmers during peak seasons.

Table 15: Oxen ownership of the sample respondent households

Number of oxen owned	Number	Percent
0	17	14.3
1	44	37
2	43	36.1
≥3	15	12.6
Total	119	100

Source: Survey result, 2017

Farmers in the sample own an average of 5.47 TLU ranging from 0.513 to 14.86 TLU. To make the unit of measurement uniform conversion factor developed by Storck *et al*., (1991) was used to convert the herd size in to TLU.

Table 16: Livestock holding of sample farmers

TLU range	Number of sample farmer	Percent
<5	56	47.06
5-10	52	43.7
>10	11	9.24
Total	119	100

Source: Survey result, 2017

Table 16 shows that 47.06 percent of the total sample farmers have had less than 5 TLU. About 43.7 percent of the total sample farmers have had TLU of which ranges between 5 and 10 TLU, and about 9.24 percent of the total households have had greater than 10 TLU.

4.1.8. Major constraints of teff production

Weed infestation, unfavorable weather condition and lack of labor in peak agricultural production season (from land preparation to weeding) were the most important problems that affect teff production. Farmers rank infestation of weed, unfavorable weather condition and shortage of labor as the most pressing problem which hinders productivity of teff, about 32.8 percent of the sample farmers rank weed infestation at first.

And 31.1 percent of sample farmers rank unfavorable weather condition as a second problem, shortage of labor, crop disease and shortage of draft animal were ranked as third, fourth and fifth important problems by the sample farmers, respectively.

Table 17: Constraints of teff production as ranked by sample farmers in the study area

Problem of teff production in the study area	Number of household	Percent	Rank
Weed infestation	39	32.8	1st
unfavorable weather condition	37	31.1	2nd
shortage of labor	31	26.1	3rd
crop disease	6	5	4th
shortage of draft animal	6	5	5th
Total	119	100	

Source: Survey result, 2017

4.1.9. Summary of production variables used in the model

This part present summary statistics results of production variables (both the physical inputs used in the production of teff output) used for analysis in the stochastic production frontier model.

Table 18: Descriptive statistics of both input and output variables

Variables	Mean	STD
Output variable		
Output (quintal)	7.1	6.21
Input variable		
Area (hectare)	0.60	0.32
Seed (kilogram)	20.78	4.30
Labor (man-day)	24.33	10.85
Urea (kilogram)	32.14	29.14
DAP (kilogram)	28.10	21.70
Oxen power(oxen-day)	8.93	5.50

Source: Survey result, 2017

The result of analysis for output variable indicates that on average a household produced 7.1 quintal of teff. The average land area allocated to teff production was approximately 0.6 hectare with a standard deviation of 0.32 hectare. The mean land size indicates that teff producers in the study area are smallholders, which also confirms that, one of the characteristics of subsistence agriculture. The mean level of labor (both family and hired) used by teff growers in the study area was found to be 24.33 man-day with 10.85 man-day difference, which was obtained by aggregating labor used for all teff production activities that include plowing, sowing, fertilizer application or top dressing and weeding. The average seed input sown was 7.28 kilogram with 4.30 quantity of difference among the farmers. Regarding fertilizer type, farmers in the study area commonly using DAP and urea fertilizer. The summary result indicates the mean rate of DAP was 28.10 kilogram with 21.70 kilogram DAP application rate variability among the farmers. The mean urea fertilizer was 32.14 kilogram with 29.14 kilogram difference among farmers. The use of oxen power in teff production activity (oxen driven activity) for example plowing in the study area is usual. The result indicated that the mean number of oxen power used was 8.93 oxen-days, with a variability of 5.5 pair of oxen days per season.

4.1.10. Summary of inefficiency variables

This part shows the review statistics of the inefficiency variables that were believed to cause technical efficiency difference among teff producers in the study area. Table 19 presents the summary statistics of both continuous and dummy efficiency variables that were included in the teff production technical efficiency model.

Table 19: Descriptive summary statistics of technical inefficiency variables

Variable	Statistical measure		
Continuous variable	Mean	STD	
Age	43.47	11.54	
Family size	5.31	2.03	
Farm size	1.90	0.87	
Meeting	12.29	7.76	
livestock holding	5.47	2.95	
Plot fragmentation	3.34	1.60	
Education	4.53	3.48	
Dummy variable	Response	Number	Percentage
Off-farm occupation	Yes (1)	24	20.2
	Not (0)	95	79.8
Credit	User (1)	47	39.5
	Non user(0)	72	60.5
Fertility status	Fertile (1)	54	45.4
	Infertile (0)	65	54.6
Slope	Gentle (1)	65	54.6
	Steep (0)	54	45.4
Time of sowing	Lately (1)	58	48.7
	Early (0)	61	51.3
Topography	Midland (1)	88	73.9
	Lowland (0)	31	26.1

Source: Survey result, 2017

2.2. Result of Econometric Analysis

Before running to the econometric analysis, multicollinearity test for all variables was done using Variance Inflation Factor (VIF) and contingency coefficient for continuous and dummy variables, respectively. According to Gujarati, 2006, value of VIF more than 10 and a contingency coefficient value of above 0.75 were usually considered as an indicator of serious multicollinearity. Given the above facts, the values of VIF for all input variables and continuous inefficiency variables were found to be within the ranges of 2.086 to 6.647 and 1.235 to 1.948, respectively (Appendix Table 2-3). The contingency coefficient values of all dummy variables were found with the ranges of 0.096 to 0.296 (Appendix Table 4).

2.2.1. Hypotheses testing

One attractive feature of SPF method is that, it is possible to test various hypotheses using maximum likelihood ratio test. Since, smallholder farmers are characterized by heterogeneity in various aspects of livelihoods like differences in resource endowments, knowledge of farming practices, and other socio-economic factors which could lead to difference in their technical efficiency. Therefore, before discussing about parameter estimates of production frontier function and the inefficiency effects, it is advisable to run the several hypotheses tests in order to choose an appropriate model for further analysis and interpretation. The following hypotheses can be tested using the generalized likelihood ratio test: $\mathrm{LR} = -2[\mathrm{L}\,(\mathrm{H}_0) - \mathrm{L}\,(\mathrm{H}_1)]$, where $\mathrm{L}(\mathrm{H}_0)$ and $\mathrm{L}(\mathrm{H}_1)$ are the values of log likelihood functions under the null and alterative hypothesis, respectively (Greene, 1993).

The first hypothesis related to the appropriateness of the Cobb-Douglas functional form in preference to translog model. To select the appropriate specification, both Cobb-Douglas and Translog functional forms were estimated (Appendix Table 1). The calculated Log likelihood Ratio (LR) is equal to 16.98 and the critical value of χ^2 at 21 degree of freedom is 32.67. The computed LR statistic was less than the tabular value at 5 percent significance level. The null hypothesis estimation results of different functional forms of stochastic production functions were accepted by indicating that the Cobb-Douglas functional form is a better representation of the data. These showed that the coefficients of the interaction terms and the square specifications of the input variables under the Translog specifications were not different from zero. Hence, the Cobb-Douglas functional form was used to estimate the technical efficiency of the sample farmers in the study area.

The next hypothesis whether the SPF is more appropriate than the Convectional production function or whether there is technical inefficiency in the production or not is tested using the null hypothesis, $H_0 : \gamma = 0$, where the parameter $\gamma = \sigma^2 u / (\sigma^2 u + \sigma^2 v)$ γ has mixed chi-square distributions. If this null hypothesis is not rejected, the SPF is equivalent to the Convectional production function which is estimated by OLS. In this case, if there is output difference among farmers given equal inputs, this difference is purely due to the difference in random shocks that are outside of the control of the farmer. This hypothesis can be tested using the generalized likelihood ratio test based on the value of log likelihood function under OLS and maximum likelihood estimation (MLE). The calculated likelihood ratio value (LR) equals to 55.21 while the critical likelihood ratio value ($\chi 2$) at 13 degree of freedom with 5percent level of significance equals to 22.36.Since the calculated LR value is greater than the critical value of $\chi 2$ at 13 degrees of freedom, rejecting the null hypothesis implies that SPF is more appropriate than Convectional production function or there is significant technical inefficiency variation among the smallholder farmers.

The third hypothesis is that the explanatory variables in technical inefficiency effect model are simultaneously equal to zero, H_0: $\delta_0 = \delta_1 - - - - - - - - - \delta_{13} = 0$. To test this hypothesis log- likelihood ratio is calculated using the value of the log likelihood function under the Cobb-Douglas stochastic frontier model (a model without explanatory variables of inefficiency effect model, H_0) and the full frontier model (a model with all explanatory variables of inefficiency effect model, H_1). The calculated value of LR equals to 50.54 while the critical likelihood ratio ($\chi 2$) of 5 percent level of significance at 13 degree of freedom equals to 22.36. Since the calculated likelihood ratio , LR , value is greater than the critical value of LR , $\chi 2$, at 13 degree of freedom with upper 5 percent level of significance, the null hypothesis that determinant variables in the inefficiency effect model are simultaneously equal to zero is rejected inefficiency effect model are jointly different from zero. This test confirms that there was inefficiency difference among the farmers due to inefficiency variables.

The last hypothesis testing is the test for returns to scale. The null hypothesis is $H_0: \beta_I = 1$ which states that the production function of the study has constant returns to scale. The test is made by first specifying a constant return model. This is done by restricting one explanatory variable over another independent variable and the dependent variable. In this case land is a restricted variable. The results of the estimation made under both model specifications, constant and variable return to scale, show that the value of log-likelihood functions equal to –81.835 and –81.833, respectively. Thus, the log likelihood-ratio test is calculated to be 0.002 and when this value is compared to the critical value of $\chi2$ at1 degrees of freedom with 1percent level of significance equals to 6.64, the null hypothesis that the Cobb-Douglas production function is characterized by constant return to scale has been accepted. The sum of the partial elasticity of all significant inputs equals to 0.996 which is almost one. This means an increase in all significant inputs at the sample mean by one percent will increase crop production in the study area by almost 1 percent. This reveals that the production function is characterized by constant returns to scale.

Table 20: Summary of hypotheses test for parameters of stochastic production function

Hypothesis	df	LH_0	LH_1	Calculated value	Critical value	Decision
1. Production Function is Cobb-Douglas H_0: C D ($\beta_7 \dots . \beta_{27} = 0$); H1=Translog production function	13	-81.833	-73.343	16.98	22.36	Accepted
2.There is no inefficiency component($H_0 : \gamma = 0$)	21	-109.438	-81.833	55.21	32.67	Not accepted
3. The coefficients inefficiency model equals zero $H_0 : \delta_0 \dots \delta_{13} = 0$	13	-107.105	-81.833	50.54	22.36	Not accepted
4.$H_0 : \Sigma \beta i = 1$	1	-81.835	-81.833	0.002	6.64	Accepted

Source: Survey result, 2017

4.2.2. Parameter estimates of the SPF model

A single stage maximum likelihood estimation procedure was employed to estimate simultaneously the parameters of both stochastic frontier production function and efficiency effect model as presented in Table 21.

Table 21: Maximum likelihood estimates of Cobb-Douglas SPF with inefficiency model

Input variables	Coefficient	Standard error	t-ratio
lnarea	0.245	0.209	1.173
lnseed	-0.232*	0.128	-1.76
lnlabor	0.361***	0.135	2.674
lnurea	-0.159	0.139	-0.114
lnDAP	0.265**	0.138	1.920
Lnoxen	0.602***	0.194	3.554
Inefficiency variables			
Age	-0.015**	0.007	-2.115
Education	-0.069***	0.024	-2.932
Family size	-0.043	0.047	-0.910
Farm size	0.366**	0.178	2.060
Off farm occupation	-0.209	0.250	-0.835
Credit	-0.055	0.167	-0.328
Meeting	0.029***	0.011	2.699
Fertility status	-0.270	0.192	-1.405
Livestock holding	-0.099***	0.042	-2.325
Slope	0.233	0.166	1.400
Plot fragmentation	-0.093	0.068	-1.369
Time of sowing	0.134	0.165	0.813
Topography	-0.290	0.229	-1.269
Sigma square	0.297***	0.055	4.811
Gamma	0.501**	0.253	1.980
LL	-81.833		

***, **, * implies significant at 1%, 5% and 10% probability level respectively

Source: Survey result, 2017

The results of the Cobb-Douglas Stochastic Production Frontier showed that the estimated coefficient for labor, DAP and oxen power were found to be positive. This positive sign confirms to a priori expectations. The estimated coefficient of labor, DAP and oxen power were found to be positively and significantly affect the level of technical efficiency of teff production. The coefficient of labor, DAP and oxen power variables are 0.361, 0.265 and 0.602, respectively. This implies that increasing the level of these inputs will shift the production function upward. This finding was line with the finding of (Bamlaku, 2009; Abebayehu Girma, 2011; Hassen Beshir, 2011), respectively. However, the input urea was found to be statistically insignificant. This implies that the amount of urea did not affect technical efficiency of teff production in the study area.

The estimated coefficient of seed was found to be negatively and significantly affect the level of technical efficiency of teff production. The coefficient of seed variable is 0.232 with negative sign. This indicates that 1 percent increase in seed usage will reduce the teff yield by 0.232 percent. This coefficient is statistically significant at 10 percent level of significant. The main reason for this negative sign is that farmers use much higher seed rate than the recommended one (8 kilogram per hectare). This finding was line with the finding of (Beyan *et al*., 2013; Abdi *et al*., 2012). On the other hand, it contradicted the finding of (Isaac, 2011).

4.2.3. Sources of technical efficiency variation

Having the information about the existence of technical efficiency variation and measuring its magnitude, examining the major factors causing technical efficiency variation is the next most important step of the study. From the very beginning about thirteen socio-economic variables were hypothesized to affect level of technical efficiency of teff growing farmers of the study area.

The coefficients of those socio-economic variables included in the model were estimated simultaneously by the MLE procedure using the estimated level of TE as dependent variable. One important point to be considered is that the dependent variable is the inefficiency component of the total error term estimated in combination with the production frontier. Hence the coefficients should be read as the effect of each variable on the level of inefficiency instead of efficiency. However, one can read the estimated coefficients directly as the effect of the variable on technical efficiency by taking the opposite sign of respective coefficients.

The coefficients of all socio-economic variables had the expected sign. However, the coefficient of plot fragmentation was appeared with unexpected sign. Out of the variables with expected sign those which were statistically significant in affecting technical efficiency differentials are age, education, farm size, meeting and livestock holding. But, the coefficients of variables such as family size, off-farm occupation, credit, fertility status, slope, plot fragmentation, time of sowing and topography were found to be statistically insignificant. The effect of these variables on the level of technical efficiency is not different from zero. This implies that these variables are less important in increasing teff yield through improvement in technical efficiency or reallocation of the existing input variables.

Age of the sample farmer

Age was found to affect technical efficiency of teff production positively. This suggested that older farmers were more efficient than their young counterparts. The reason was age can serve as a proxy variable of farming experience, in which farmers with more years of experience are expected to be more efficient. This finding was line with the finding of (Shumet Assefa, 2011; Solomon Buziyehu, 2014). But it contradicted the finding of (Bekele Alemayehu, 2013).

Table 22: Age of farmers and mean level of technical efficiency

Age group	Number	Percent	Mean TE
<=30	17	14.29	54.18
31-50	69	57.98	54.88
>50	33	27.73	71.73
Total	119	100	

Source: Survey result, 2017

As table 22 above shows that those sample farmers with less than and equal to 30 year of age were technically efficient by an average of 54.18 percent and those sample farmers with the range of 31 to 50 year of age were technically efficient by an average of 54.88 percent. Those sample farmers who have above 50 year of age were technically efficient on an average of 71.73 percent. This result confirmed that as age of the sample farmer increase they become more technically efficiency. The reason is that older sample farmers in the study area were wealthy when they compare with the younger sample farmers. This made older sample farmers to hire additional labor, to purchase chemical fertilizers and to carry out farming activities on time. As it was mentioned in the appendix table 8 the weekly income of sample farmers increases with their age.

Education level of household head

Education equips farm household with the necessary knowledge of how to allocate their scarce resource in appropriate way by increase the adoption and spread technological innovations that shifts their production frontier outward. Educated farmers have strong desire to get information and use it than their counterpart. Thus, this variable is a powerful variable in determining the technical efficiency variation among teff producers since it increases decisions of the farmer to adopt productivity enhancing technologies. Then, this variable affects technical efficiency positively and statistically significant at 10 percent significance level. This finding of the study was similar with finding of (Dlamini *et al*., 2010; Getahun Gemechu, 2014; Addai and Owusu, 2014).

Table 23: Education level of sample farmers and their mean technical efficiency

c	Number	Percent	Mean TE
0-1	38	31.93	53.61
2-6	43	36.13	59.07
7-8	22	18.49	62.27
>=9	16	13.45	70.50
Total	119	100	

Source: Survey result, 2017

As table 23 shows that those sample farmers who have education level between 0 and 1 were technically efficient by an average of 53.61 percent and those sample farmers who have education level with the range of 2 to 6 were technically efficient by an average of 59.07 percent. Those sample farmers who have education level between 7 and 8 were technically efficient by an average of 62.27 percent and those sample farmers who have education level above and equal to 9 were technically efficient by an average of 70.50 percent. This result shows that as the education level of the sample farmers increase their technical efficiency level also increase in the same direction.

Farm size

Farm size is measured as total land cultivated by the farmer including those rented and shared. In this study, it was hypothesized that the effect of this variable on technical efficiency was ambiguous i.e. it may be positive or negative. The estimated result showed negative relationship between farm size and technical efficiency. This may be, due to as farm size increase, the farm manageability ability of the farmers decrease. This was in agreement with the finding of (Mekdes Abera, 2013; Endrias *et al*., 2013). On the other hand, it contradicted the finding of (Tefera *et al*., 2014).

Table 24: Total crop land hold by sample farmers and their mean technical efficiency

Farm size	Number	Percent	Mean technical efficiency
<3 hectare	102	94	59.76
>=3 hectare	7	6	54.57
Total	119	100	

Source: Survey result, 2017

As table 24 shows that those sample farmers who have less than 3 hectare of land were technically efficient by an average of 59.76 percent and those sample farmers who have greater than and equal to 3 hectare of land were technically efficient by an average of 54.57 percent. This result confirmed that as the size of farm increase the technical efficiency level of sample farmers' decrease.

Livestock holding (TLU)

It was hypothesized that the effect of this variable on technical efficiency was ambiguous i.e. it may be positive or negative. The estimated result showed positive relationship between livestock holding and technical efficiency. The reason is that livestock could support crop production in many ways; it can be source of cash (from sale of milk and milk products and sale of alive livestock to buy improved agricultural technologies), draft power and manure that will be used to maintain soil fertility. This finding was consistent with the finding of (Mohammed *et al*., 2010; Essa *et al.,* 2011). On the other hand, it contradicted the finding of (Hassen Beshir, 2016).

Table 25: Sample farmers' livestock holdings and their mean technical efficiency

TLU range	Number	Percent	Mean technical efficiency
<5	56	47.06	47.20
5-10	52	43.7	67.24
>10	11	9.24	85.00
Total	119	100	

Source: Survey result, 2017

As table 25 shows that those sample farmers who have less than 5 TLU were technically efficient by an average of 47.20 percent and those sample farmers who have TLU between 5 and 10 were technically efficient by an average of 67.24 percent. Those sample farmers who have greater than 10 TLU were technically efficient by an average of 9.24 percent. This result shows that as TLU increase the technical efficiency level of sample farmers also increase.

Meeting

Meeting has been found to be an important variable in explaining the variation of technical efficiency among farmers. The negative and significant impact of meeting in this study implies that repeating meeting make farmers to delay farming activities by reducing the availability of labor force in the production process as well as the managerial role of household. As mentioned in the descriptive part the sample farmer wasted on average 12.29 hours in meeting in a week. Table 26 shows the mean TE of the sample farmers below and above the mean level of hours spent in meeting was 69.43 and 45.20 percent, respectively. The mean TE difference was 24.23 percent. This indicates that meeting has large effect on technical efficiency variation.

Table 26: Spent hours in meeting and mean TE of the sample farmers

Total hours spent in meeting	Number of household	Percent	Mean TE	Sta.dev	t-value
< 12.29	70	58.82	69.43	0.18	-7.12***
>=12.29	49	41.18	45.20	0.19	

Note: *** indicates significance at 1 percent level

Source: Survey result, 2017

4.2.4. Variability of output due to technical efficiency differentials

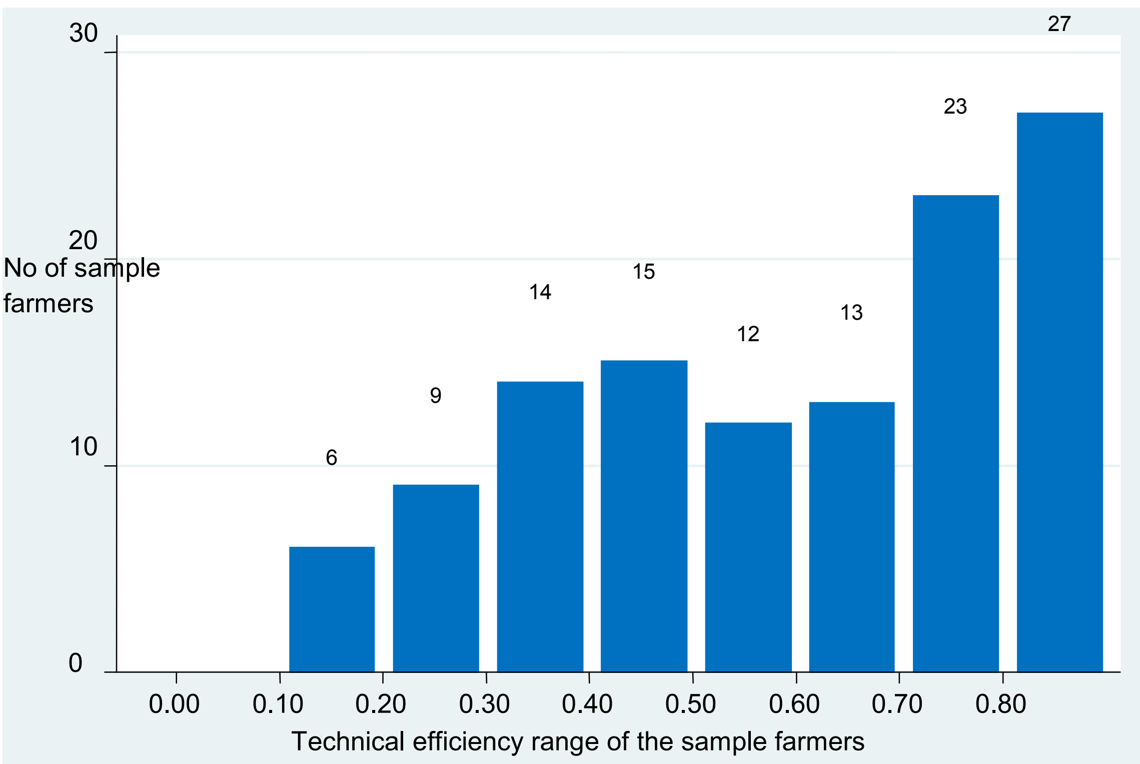
The Maximum Likelihood estimation of the frontier model was given the value for the parameter(γ), which is the ratio of the variance of the inefficiency component to the total error term $\gamma = \sigma^2 u \,/\, \sigma^2 v + \sigma^2 u = \sigma^2 u/\sigma^2 s$. The γ value indicated the relative variability of the one sided error term to the total error-term. In other words, it measured the extent of variability between observed and frontier output that is affected by the technical inefficiency. The discrepancy ratio (γ) of teff output indicates that 54 percent of teff output variability is due to technical inefficiency between the sample farmers while the remaining 46 percent is due to the effect of the disturbance term. This indicates that there is more opportunity to enhance the low productivity of sample producers through identification of source of technical efficiency variation.

4.2.5. Scores of technical efficiency

The study area’s average farmer’s level of technical efficiency was estimated to be 59.5 percent. This indicates that farmers are not efficient in producing teff and teff yield can be increased on average up to 40.5 percent by taking examples of more efficient farmers without disseminating any new technologies. It is an indication to the farmers that there is a possibility of minimizing input level by up to 40.5 percent without affecting the level of output.

There is a considerable difference in technical efficiency among farmers that ranged from a minimum of 0.16 to a maximum of 0.91 (appendix table 7). About 47 percent of teff growing farmers were producing teff yield below the overall mean technical efficiency level of the farmers, whilst almost 53 percent of teff growing farmers were able to produce teff yield above the mean efficiency level and about 23 percent of teff growing farmers were producing teff yield above 80 percent of efficiency level.

Figure 6: Distribution of farmers by technical efficiency scores



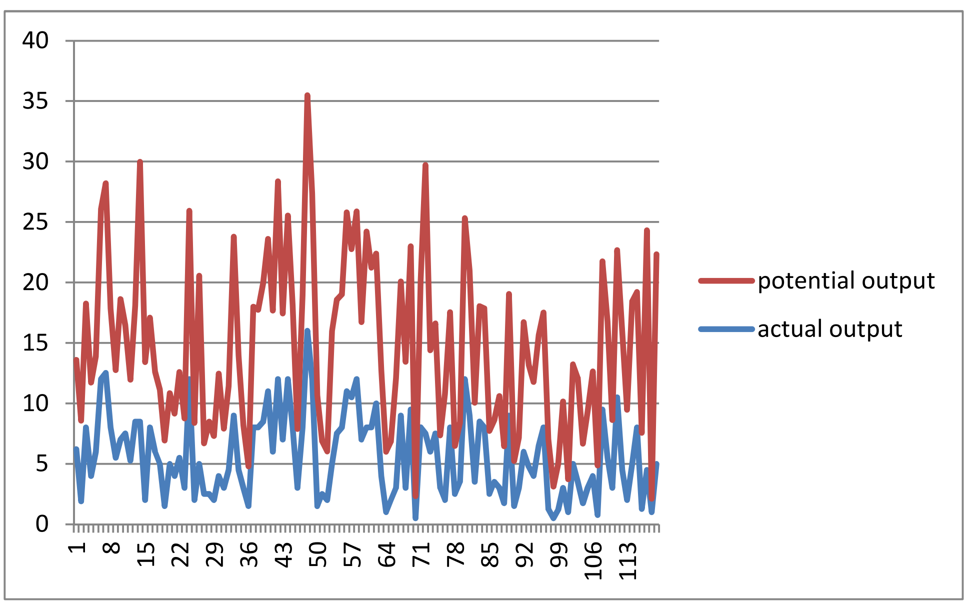
Source: Survey result, 2017

Figure 3 shows that about 13, 24 and 40 percent of the sample farmers scored technical efficiency level less than 0.3, between 0.3 to 0.5 and 0.51 to 0.8, respectively. About 23 percent of sample farmers scored above 0.8 technical efficiency levels.

4.2.6. Estimated actual and potential level of teff output

The variation between the actual and the frontier level of output was carried out by estimating the individual and the mean level of frontier from stochastic model. Using the values of the actual output obtained and the predicted technical efficiency indices, the potential output was estimated for each sample farm households. As it was mentioned in the appendix table 9 the mean levels of the actual and potential output during the production year were 5.61 quintal per hectare and 9.16 quintal per hectare, with the standard error of 0.31 and 0.37, respectively. Moreover, independent sample t-test was used on the actual and potential yield to compare the difference in the amount of yield between two scenarios. There was a significant difference between potential yield and actual yield. The mean difference of the actual and the potential output was found to be statistically significant at 1 percent probability level. The results show the existence of technical inefficiencies in the study area. The actual output can be calculated as: $Y_i = \exp(X_i\beta + V_i - U_i)$ and the potential output on the other hand is expressed as $Y_i = \exp(X_i\beta + V_i)$.

Figure 7: Comparison of the actual and the potential level of teff yield



Source: Survey result, 2017

As Figure 7 illustrates that under the existing practices there is a room to increase teff yield following the best-practiced farms in the study area. There was 442.45 quintals of teff yield gap in the study area. As appendix table 8 shows that it was observed that mean technical inefficiency was 40.6 percent which caused 3.55 quintal per hectare yield gap of teff on the average with mean value of the actual output and the potential output of 5.61 quintal per hectare and 9.16 quintal per hectare, respectively. This shows that sample farmers in study area were producing on the average 3.55 quintal per hectare lower teff output than their potential yield. Finally, there was 422.45 quintals of teff yield gap in the study area.

4.2.7. Marginal Effects of inefficiency variables

The estimated parameters on the inefficiency model presented in Table 21 only indicated the direction of the effects that the variables had on inefficiency levels in contrast the marginal effect presented on table 27 below indicates the effect of inefficiency variables on technical efficiency level. According to Battese and Coelli (1995), quantification of the marginal effects of inefficiency variables on technical efficiency was done by partial differentiation of the technical efficiency predictor with respect to each variable in the inefficiency function.

Table 27: Marginal effect of efficiency variables among sample farmer heads

Variable	dy/dx	SE	Z	Change in TE in percent
Age	0.017**	0.006	3.04	1.7
Education	0.177*	0.123	1.45	17.7
Farm size	-0.320**	0.112	-2.85	32.0
Meeting	-0.024**	0.009	-2.83	2.4
livestock holding	0.058**	0.026	2.21	5.8
Topography	0.526***	0.152	3.47	52.8

*, **, *** implies significant at 10 percent and 5 percent and 1 percent probability level respectively

Source: Survey result, 2017

The marginal effect of age of sample farmer 0.017 indicated that as the age of sample farmer increase by one year, on average technical efficiency of the sample farmer will increase by 1.7 percent. As the number of livestock increases by one TLU, on average the farmer's technical efficiency increase by 5.8 percent. In contrast the marginal effect of farm size -0.32 showed that for the sample farmer an increase in farm size by one hectare on average technical efficiency of the sample farmer will decrease by 32 percent. When the sample farmer incur or spend one hour in meeting, on average the technical efficiency of the farmer decrease by 2.4 percent. The marginal effect for topography can be interpreted as, if farmers sow teff in midland instead of lowland, on average the technical efficiency of sample farmer increase by 52.8 percent. This indicates that the highest effect of agro-ecology on technical efficiency.

4.2.8. The effect of agro-ecological zone on technical efficiency

Teff was produced in lowland and midland areas of the study area. As one moves across agro-ecological zone, the level of technical efficiency is varied. The level of technical efficiency is low in the lowland area than midland area. The reason may be since temperature is relatively higher in lowland area which is comfortable for the prevalence of teff diseases in lowland area. As key formants explained teff plant is attacked by a best known disease in the local farmers is called kitgn that makes the plant growth stunt in the lowland area. The result of independent sample t test to shows that there is significant mean technical efficiency difference between lowland and midland agro-ecological zones.

Table 28: Means TE score across agro-ecological zone

Agro ecology	Maximum	Minimum	Mean TE	t-ratio
Midland	0.91	0.18	0.64	4.027 ***
Lowland	0.90	0.16	0.47	

*** implies significant at 1 percent probability level

Source: Survey result , 2017

As table 28 shows that the mean technical efficiency of midland and lowland area of sample farmers in the study area was 0.64 and 0.47, respectively. The mean TE difference between midland and lowland was 0.17 (17 percent). This indicates that there was TE variation across agro-ecological zone. The reason is that lowland area is poverty stricken area and the availability of markets and institutions is low due to road transportation problem. The supply of modern inputs is not available on time.

Table 29: Variables means difference across midland and lowland sample farmers

Variables	Midland	Lowland	t- ratio
Output (quintal)	8.0	4.5	2.75**
DAP(kilogram)	40.13	9.87	5.57***
Urea(kilogram)	34.20	10.78	5.86***
Seed (kilogram)	6.93	8.29	-1.53*

*, **, *** implies significant at 10 percent and 5 percent and 1 percent probability level respectively

Source: Survey result, 2017

Table 29 shows that, the mean of sample farmer's teff output in midland and lowland was 8 and 4.5 quintal, respectively. The mean level of DAP and urea in midland and lowland was 40.13, 9.87 and 34.20, 10.78 kilogram, respectively. The mean level of seed in midland and lowland was 6.93 and 8.29 kilogram, respectively. As it is showed in the above table, there is wide mean difference of output, DAP, urea and seed between midland and lowland in the study area. Based on this result, separate production frontiers for sample farmers are estimated for further explore the effect of agro-ecological zone on technical efficiency.

Table 30: The MLE estimates in midland and lowland agro-ecological zones

Variable	Midland		Lowland	
	Coeff.(SE)	t-value	Coeff.(SE)	t-value
Lnarea	0.242(0.233)	1.037	0.197(0.002)	98.667***
Lnseed	-0.210(0.181)	-1.159	-0.044(0.002)	-18.308***
Lnlabor	0.408(0.156)	2.610***	0.783(0.0007)	1086.764***
Lnurea	-0.102(0.191)	-0.533	-0.070(0.0003)	-224.742***
LnDAP	0.319(0.171)	1.862**	0.263(0.0006)	397.327***
Lnoxen	0.404(0.226)	1.791**	0.523(0.0007)	745.320***
Age	-0.013(0.013)	-0.985	-0.012(0.018)	-0.623
Education	-0.099(0.060)	-1.643*	-0.418(0.321)	-1.303
Family size	-0.010(0.064)	-0.158	-0.199(0.155)	-1.289
Farm size	0.622(0.371)	1.672*	-0.116(0.238)	-0.489
Off-farm occupation	-0.167(0.375)	-0.447	-0.348(0.845)	-0.411
Credit	-0.030(0.272)	-0.109	-0.933(0.390)	-2.392***
Meeting	0.030(0.015)	1.991**	0.037(0.028)	1.339
Fertility status	-0.123(0.322)	-0.383	-0.594(0.427)	-1.390
Livestock holding	-0.131(0.103)	-1.270	-0.100(0.855)	-1.167
Slope	0.182(0.285)	0.639	-0.163(0.377)	-0.433
Land fragmentation	-0.154(0.120)	-1.29	0.364(0.146)	2.478***
Time of sowing	0.137(0.253)	0.540	-0.513(0.356)	-1.443
Inefficiency effect model				
Sigma-squared	0.306(0.114)	2.698***	0.280(0.036)	7.731***
Gamma	0.556(0.237)	2.343***	0.95(0.002)	472.08***
LL	-59.410		-2.816	
Total sample size	88		31	
Mean TE	63.23		52.43	

, * implies significant at 5 percent and 1 percent probability level respectively

Source: Survey result, 2017

As table 30 depicts that all inputs were found to be significant in the lowland area while labor, DAP and oxen were found to be significant in the midland area. The positive estimated coefficients of area, labor, DAP and oxen confirms that an increase in quantities of these inputs would result in an increase in output. The negative estimated coefficients of seed and urea imply that an increase in the quantities of these inputs would result in a decrease in output.

The estimated coefficient of seed was found to be negatively and significantly affect the level of technical efficiency of teff production in lowland agro-ecological zone. The coefficient of seed variable was 0.21 with negative sign in lowland. This shows that 1 percent increase in seed usage will decrease teff yield by 0.21 percent. This coefficient is statistically significant at 1 percent level significant. The main reason for this negative sign is that farmers use much higher seed rate (20.76) kilogram per hectare than the recommended one (8-12) kilogram per hectare as it was described in the descriptive part. This finding was line with the finding of (Abdi *et al*., 2012; Beyan *et al*., 2013). On the other hand, it contradicted the finding of (Isaac, 2011).

The estimated coefficient of urea was found to be negatively and significantly affect the level of technical efficiency of teff production in lowland agro-ecological zone. The coefficient of urea variable was 0.07 with negative sign in lowland agro-ecological zone. This shows that 1 percent increase in urea usage will decrease teff yield by 0.07 percent. This coefficient is statistically significant at 1 percent level significant. The reason is that in the 2015 summer season the amount of rainfall is low in the study area due to ilino. In the study area urea is sown at the end of August on the green plant of teff with no or very little rainfall. When urea is sown with no rainfall, it affects the growth of teff plant negatively. As the amount of urea increase with no rain fall the growth of teff plant become stunt due to the acidity of the urea. This finding was line with the finding of (Bekele Alemayehu, 2013). On the other hand, it was inconsistence with the finding of (Abebe Dagnew, 2009).

The estimated coefficient of area was found to be positively and significantly affect the level of technical efficiency of teff production in lowland agro-ecological zone at 1 percent level significant. The coefficient of area was 0.197 which shows that 1 percent increase in the area of teff plot will increase teff yield by 0.197 percent. The reason is that as the area of teff plot increase the sample farmers concentrated on farming activities. This finding was line with the finding of (Hailemaraim Leggesse, 2015).

The estimated coefficient of labor was found to be positively and significantly affect the level of technical efficiency of teff production in both agro-ecological zones (lowland and midland) at 1 percent level of significant. A 1 percent increase in labor in lowland and midland will increase teff yield by 0.783 and 0.408 percent, respectively. This finding was line with the finding of (Hasssen Beshir, 2011).

The estimated coefficient of DAP was found to be positively and significantly affect the level of technical efficiency of teff production in lowland and midland at 1 percent and 5 percent level of significant, respectively. A 1 percent increase in DAP in lowland and midland will increase teff yield by 0.263 and 0.319 percent, respectively. This finding was line with the finding of (Abebayehu Girma, 2011)

The estimated coefficient of oxen power was found to be positively and significantly affect the level of technical efficiency of teff production in lowland and midland at 1 percent and 5 percent level of significant, respectively. A 1 percent increase in oxen in lowland and midland will increase teff yield by 0.523 and 0.404 percent, respectively. This finding was line with the finding of (Bamlaku *et al*., 2009)

As table 30 above shows that out of 12 inefficiency variables 3 and 2 variables were statistically significant in midland and lowland, respectively. Education, farm size and meeting were found to be statistically significant inefficiency variables in midland agro-ecological zone of the study area. Credit and land fragmentation were found to be statistically significant inefficiency variables in lowland agro-ecological zone of the study area. As it was showed in the above table the effect on inefficiency variables on technical efficiency in midland and lowland agro-ecological zones were different. This result confirms that there is technical efficiency difference between midland and lowland agro-ecological zones.

The estimated result showed that significant and positive relationship between education and technical efficiency for midland sample farmers. The reason is that education enhances the acquisition and utilization of information on improved technology. This finding was consistent with the finding of (Asefa Solomon, 2012). However, education has no impact on technical efficiency of lowland sample farmers.

The estimated result showed that a significant and negative relationship between farm size and technical efficiency for midland sample farmers. The reason is that as farm size increase manageability ability of the sample farmer decrease. This finding was consistent with the finding of (Endrias *et al*., 2013). However, farm size was insignificant in lowland agro-ecological zone. That means farm size has no impact on technical efficiency of lowland sample farmers.

The estimated result showed that a significant and negative relationship between meeting and technical efficiency for midland sample farmers. The negative and significant impact of meeting in this study implies that repeating meeting make farmers to delay farming activities by reducing the availability of labor force in the production process as well as the managerial role of household. However, meeting was insignificant in lowland agro-ecological zone. That means meeting has no impact on technical efficiency of lowland sample farmers.

The estimated result showed that a significant and positive relationship between credit and technical efficiency for lowland sample farmers. The reason is that lowland areas are poverty stricken area and the availability of credit access increase cash for those households to buy modern agricultural inputs on time. This finding was consistent with the finding of (Adil and Hanan, 2015). However, credit was insignificant in midland agro-ecological zone. That means credit access has no impact on technical efficiency of midland sample farmers.

The estimated result showed that a significant and negative relationship between land fragmentation and technical efficiency for lowland sample farmers. This is due to the fact that it would become less effective and less accessible to manage each plot if they are large in number and scattered. This finding was consistent with the finding of (Fekadu Gelaw and Bezabih Emana, 2009; Beckhman *et al*., 2010). However, land fragmentation was insignificant in midland agro-ecological zone. That means land fragmentation has no impact on technical efficiency of midland sample farmers.

As the maximum likelihood estimate in table 30 indicates that the mean technical efficiency level of lowland and midland sample farmers are about 52 and 63 percent, respectively. The mean technical efficiency difference between lowland and midland agro-ecological zones is about 11 percent. It shows that there is technical efficiency variation between lowland and midland agro-ecological zones.

5. SUMMARY, CONCLUSIONS AND POLICY RECOMMENDATIONS

In this chapter the overall conclusion is presented based up on the analyses conducted in the previous chapter and relevant policy recommendations are drawn from the conclusion.

5.1. Summary and Conclusions

The main objective of this study was measuring technical efficiency level of teff producers in Legehida Woreda and identifying those factors which affect production efficiency. Data were collected by interviewing a total of 119 sample farmers using a semi structured interview schedule that includes questions related to socio-economic factors such as demographic characteristics, institutional factors, inputs and output characteristics and farm specific factors.

Stochastic frontier production function in which the technical inefficiency factors are assumed to be a function of socio-economic variables were estimated. The data set was analyzed by SPF after employing a generalized likelihood ratio test to select from an ordinary average expression of production function. The data has been analyzed in a one stage procedure which constitutes six input variables in frontier function and thirteen explanatory variables in an inefficiency model.

The hypothesis that technical efficiency effects are absent, given the specification of Cobb-Douglas stochastic frontier production function, was rejected based on the results of the econometric model. This shows that the technical inefficiency exists in the sample farmers considered and hence, the average response function that all farmers are fully technically efficient is not supported by the result obtained from statistical analysis of the data.

Production frontier was estimated by taking input variables like area of teff plot, labor, DAP, amount of seed, oxen power, DAP and urea use. Labor and oxen power are found to be strongly significant (at 1 percent significance level) inputs to determine output level of teff in the study area as the whole. Seed is significant at 5 percent, whereas area, DAP and urea were found to be factors that do not determine production level of teff in the study area as the whole.

Coefficients of the input variables are interpreted as the elasticity of output with respect to each input variable. As coefficients of significant maximum likelihood estimates shows that a 1 percent increase in units of labor, DAP and oxen power would increase output of teff by 0.361, 0.265 and 0.602 percent, respectively in the study area as the whole. On the other hand, as the amount of seed increase by 1 percent, the level of teff output decrease by 0.232 percent in the study area as the whole.

To know the impact of agro-ecological zone on technical efficiency a separate production frontier analysis was carried out for lowland and midland agro-ecological zones. The result shows that all input variables found to be strongly significant (at 1 percent significance level) to determine output level of teff for lowland sample farmers. DAP and oxen were significance at 5 percent where as labor was significance at 1 percent to determine output level of teff for midland sample farmers. Area, seed and urea were found to be factors that do not determine output level of teff for midland sample farmers.

The positive coefficient of labor, DAP and oxen shows that an increase the amount of those inputs will increase the level of technical efficiency for both lowland and midland sample farmers. The positive coefficient of area indicates that increasing the amount of this input will increase the level of technical efficiency for lowland sample farmers. The negative coefficient of seed and urea confirms that increasing the amount of those inputs will decrease the level of technical efficiency for lowland sample farmers. Therefore, it is concluded that different input variables have different impact on the level of technical efficiency across agro-ecological zones.

The average efficiency level of teff producers in the study area as the whole, midland and lowland was 59.5, 63 and 52 percent respectively. Thus, the conclusion that can be draw from this study is that there was efficiency variation among sample farmers in the study area and teff production can be increased by 40.5, 37 and 48 percent through better use of the available resources in the study area as the whole, midland and lowland respectively. This is an indication that increasing efficiency of relatively inefficient farmers and those operating closer to the frontier would help them to minimize input use by up to 40.5, 37 and 48 percent in the study area as the whole, midland and lowland areas respectively.

The sources of technical efficiency differential were estimated using the δ-coefficients. Inefficiency factors are those relating to farmers' socio-economic factors. These include the farmers' level of education, off farm occupation, meeting, credit accessibility, farm size, fragmentation, slope, fertility status, family size, age, livestock holding and time of sowing.

Among the variables considered family size, off-farm occupation, slope, credit and fertility status, fragmentation, topography and time of sowing are insignificant to determine technical efficiency of small holder farmers in the study area as the whole. Negative and significant coefficients of age, education and livestock holding indicate that technical efficiency level of farmers would be increased as the level of these factors increase in the study area as the whole. On contrary, positive and significant coefficients of meeting and farm size implies that farmers unable to utilize the available inputs efficiently in the study area as the whole.

Education, farm size and meeting were significant variables in the midland area where as credit and land fragmentation were significant variables in the lowland areas. Positive and significant coefficient of meeting and farm size indicate that technical efficiency level of farmers would be decreased as the level of these factors increase in midland area. The negative and significant coefficient of education indicates that technical efficiency level of farmers would be increased as the level of this factor increase in midland area. The positive and significant coefficient of land fragmentation shows that technical efficiency will decrease with increasing number of land fragmentation in lowland area. The negative and significant coefficient of credit shows that credit avoid financial problem which is obstacle to purchase modern agricultural inputs in lowland area. It confirms that socio-economic and institutional variables have different impact across agro-ecological zones.

In general, the SPF model showed that production can be improved by increasing the use of inputs. There is considerable room to improve the efficiency of farmers in teff production. The implication is that, there will be considerable gain in production level if introduction and distribution of agricultural technologies is joined with improving the existing level of efficiency.

5.2. Policy Recommendations

The suggestion of this study is that technical efficiency of the farmers can be increased by 40.5, 40 and 48 percent in the study area as the whole, midland and lowland, respectively, through better allocation of the available resources. Thus, government or other concerned bodies in the developmental activities working with the view to enhance production efficiency of farmers in the study area should work on improving productivity of farmers by giving especial emphasis for significant inputs and inefficiency variables.

The result of the study reveals that increasing area of land decreases farmers' efficiency. Hence rather than expanding land allocation, it is important to improve productivity of land through increasing use of organic fertilizer such as compost, manure etc and proper use of chemical fertilizer.

Education of sample farmers, measured in years of schooling affects technical efficiency of teff producing farmers. This indicates that education is fundamental in improving the technical efficiency thereby the performance of sample farmers. Hence, government should have designed appropriate policy to provide adequate and effective basic educational opportunities to the rural population, both formal and non-formal education for farmers in the study area so that farmers can use the available inputs more efficiently under the existing technology seems crucial.

The result of the study reveals that meeting has a negative influence on technical efficiency. The government should reduce excessive meeting by rearranging the meeting program from peak agricultural production to off season.

Livestock holding was positively significant on technical efficiency. Hence, there is a need to design appropriate policy and strategies for improving livestock production systems by solving the shortage of feed and providing various technical and advisory support services, which in turn would enhance the efficiency of teff production in the study area as the whole.

The study result shows that credit access has positive impact on technical efficiency of lowland sample farmers. Credit access empowers smallholder farmers to purchases inputs that they cannot afford from their own resources, which enhance production and productivity of lowland teff producing farmers. Hence, the government should establish and expand the service given by credit providing institutions such as microfinance institutions and agricultural cooperatives to assist farmers in terms of financial support through credit are crucial to improve farm productivity in the lowland area.

Finally, the existing level of efficiencies in teff production in the study area as the whole, in midland and in lowland areas are high and this calls for better attention of policy makers and researchers in tackling the sources of these inefficiencies to improve the welfare of teff producing farmers in both agro-ecological zones.

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7. APPENDIXES

Appendix 1: Estimation results of different functional forms of stochastic production functions

Cobb-Douglas				Translog		
variable	coeff	SE	t-ratio	coeff	SE	t-ratio
constant	5***	0.76	6.58	17.6	1.07	16.46
lnarea	0.245	0.209	1.173	8.15	1.05	7.78
lnseed	-0.232*	0.158	-1.466	-7.97	1.52	-5.24
lnlabor	0.361***	0.135	2.674	-2.94	0.945	-3.11
lnurea	-0.159	0.139	-0.114	0.84	0.864	0.97
lnDAP	0.265**	0.138	1.920	-1.13	0.816	-1.39
lnoxen	0.602***	0.194	3.554	2.81	0.916	3.06
lnarea^2				0.89	0.336	2.66
lnseed2				0.20	0.336	0.62
lnlabor^2				-0.06	0.22	-0.26
lnDAP^2				-0.17	0.30	-0.59
lnUrea^2				0.12	0.30	0.38
lnOxen^2				-0.46	0.47	-0.99
lnarea*lnseed				-0.165	0.60	-2.76
lnarea*lnlabor				-1.15	0.43	-2.65
lnarea*lnDAP				0.48	0.47	1.02
lnarea*lnurea				-0.92	0.39	-2.32
lnarea*lnoxen				0.60	0.49	1.20
lnseed*lnlabor				1.40	0.56	2.50
lnseed*lnDAP				-0.66	0.49	-1.33
lnseed*lnurea				0.75	0.63	1.19
lnseed*lnoxen				0.55	0.58	0.94
lnlabor*lnDAP				0.55	0.47	1.17
lnlabor*lnurea				-0.14	0.55	-0.25
lnlabor*lnoxen				-0.48	0.51	-0.93
lnDAP*lnurea				-0.25	0.51	-0.49
lnDAP*lnoxen				0.40	0.56	0.72
lnurea*lnoxen				-0.13	0.57	-0.22
sigma-squared	0.297	0.066	4.496	0.29	0.08	3.71
gamma	0.54	0.199	2.70	0.45	0.14	3.17
Mean TE	0.59				0.76	
LL function	-81.83				-73.34	

Source: Survey result, 2017

Appendix 2: VIF for the variables entered in to the SPF model

Variable	R^2	$1-R^2$	VIF
lnarea	0.820	0.180	5.559
lnseed	0.747	0.253	3.955
lnlabor	0.521	0.479	2.086
lnurea	0.850	0.150	6.647
lnDAP	0.829	0.171	5.864
lnoxen	0.768	0.232	4.308
Mean VIF			4.737

Source: Survey result, 2017

Appendix 3: The VIF for the continuous variables used in inefficiency variables

Inefficiency variable	R^2	$1-R^2$	VIF
Age	0.190	0.810	1.235
Labor	0.236	0.764	1.310
Meeting	0.257	0.743	1.346
Fragmentation	0.360	0.640	1.561
Livestock holding	0.375	0.625	1.601
Farm size	0.487	0.513	1.948
Education	0.210	0.790	1.266
Mean VIF			1.467

Source: Survey result, 2017

Appendix 4: Contingency coefficient of socio-economic variables

	Off-farm occupation	Credit	Fertility status	Slope	Time of sowing	Topography of teff plot
Off-farm occupation	1					
Credit	0.267	1				
Fertility status	0.210	0.114	1			
Slope	0.202	0.225	0.277	1		
Time of sowing	0.096	0.166	0.090	0.111	1	
Topography of teff plot	0.199	0.107	0.296	0.292	0.228	1

Source: Survey result, 2017

Appendix 5: Conversion Factors used to compute Man-Equivalent

Age group (years)	Male	Female
<10	0	0
11-13	0.2	0.2
14-16	0.5	0.4
17-50	1.0	0.8
>50	0.7	0.5

Source: Strock *et al*., 1991

Appendix 6 : Conversion factors used to estimate Tropical Livestock Unit (TLU)

Animal category	TLU
Calf	0.25
Donkey (young)	0.35
Heifer	0.75
Sheep and goat (adult)	0.13
Sheep and goat (young)	0.06
Cow and ox	1.00
Donkey (adult)	0.70
Horse and mule	1.10
Chicken	0.013

Source: Strock, *et al*., 1991

Appendix 7 : Technical efficiency level of sample farmers

Description	Household head level estimates in percent
Mean	0.595
Maximum	0.910
Minimum	0.160
Standard deviation	0.218

Source: Survey result, 2017

Appendix 8: Age of sample farmer and their mean weekly income

Age of household	Number	Percent	Mean weekly income in birr
28-50	86	72.27	164.35
51-80	33	27.73	255.79
Total	119	100	

Source: Survey result, 2017

Appendix 9: Comparison of actual yield and potential teff yield

Output	Maximum	Minimum	Mean	STD
Actual output(quintal per hectare)	16	0.5	5.61	3.39
Potential output (quintal per hectare)	22.21	1.11	9.16	4.15

Source: Survey result, 2017

Appendix 10: Technical efficiency estimates of farmers

Farmers ID	TE	Farmer ID	TE	Farmer ID	TE
1	0.84	41	0.51	81	0.75
2	0.28	42	0.73	82	0.53
3	0.78	43	0.67	83	0.89
4	0.52	44	0.89	84	0.81
5	0.76	45	0.79	85	0.48
6	0.85	46	0.62	86	0.69
7	0.80	47	0.73	87	0.39
8	0.81	48	0.82	88	0.37
9	0.76	49	0.78	89	0.89
10	0.60	50	0.16	90	0.40
11	0.84	51	0.57	91	0.72
12	0.78	52	0.50	92	0.56
13	0.88	53	0.46	93	0.56
14	0.40	54	0.68	94	0.52
15	0.18	55	0.73	95	0.71
16	0.88	56	0.74	96	0.84
17	0.91	57	0.86	97	0.21
18	0.81	58	0.86	98	0.19
19	0.28	59	0.72	99	0.31
20	0.86	60	0.49	100	0.42
21	0.78	61	0.61	101	0.37
22	0.78	62	0.81	102	0.61
23	0.52	63	0.46	103	0.41
24	0.86	64	0.20	104	0.36
25	0.31	65	0.41	105	0.47
26	0.32	66	0.33	106	0.46
27	0.60	67	0.81	107	0.18
28	0.42	68	0.29	108	0.78
29	0.38	69	0.70	109	0.49
30	0.47	70	0.28	110	0.53
31	0.61	71	0.66	111	0.86
32	0.65	72	0.34	112	0.39
33	0.61	73	0.72	113	0.27
34	0.48	74	0.82	114	0.37
35	0.58	75	0.69	115	0.71
36	0.46	76	0.23	116	0.20
37	0.80	77	0.84	117	0.23
38	0.82	78	0.63	118	0.90
39	0.74	79	0.71	119	0.29
40	0.87	80	0.90		

Source: Survey result, 2017

A questionnaire prepared for studying technical efficiency of teff production in Legehida Woreda.

1. General description of the respondent

1.1. Household number (code) ___________________________

1.2. Name of household head________________________ Age __________

1.3. Sex: 1. Male (M) 2. Female (F)

1.4. Rural Keble Administration (KA) ______________Locality (Gote) __________

1.5. Marital status: 1. Married 2. Not married 3. Divorced 4. Widowed

1.6. Education level: 1) Illiterate 2) Literate Read and write(R&W) or, If, you attained in school indicate your educational level number in grade_____________

1.7. Religion: 1. Christian 2. Muslim 3. Protestant 4.others _________________

1.8. Farming experience ___________years

1.9. What is your total land holding (measured in timad)?____________________

1.10. How many of your land coverage is under crop production (measured in timad)?_______

1.11. What is the total area of your teff plot in timad?_____________

1.12. Household members

Sex	Age category					Remark
	< 10	10-13	14-16	17-50	>50	
Male						
Female						
Total						

2. Input utilization for teff production

2.1. What is the total area of your teff plot in hectare?_______________

2.2. How many (Kg) of teff output is used

For Seed? __________

For home consumption? ____________

To sell? ______________

2.3. How many pairs of oxen did you apply from land preparation up to sowing?________

2.4. Do you use chemical fertilizer in teff field?

1. Yes 2. No

2.5. If yes, what type of fertilizer?

1. DAP 2. Urea 3. Both 4. Other, specify____________

2.6. How many kg of DAP per hectare do you use for teff? _______________

2.7. How many Kg of urea per hectare do you use for teff? _______________

2.8. If you do not use fertilizer, why?

1. Too expensive 2. Inconvenient to transport

3. No timely available 4. Not available 5. Not good to apply on teff field 6. Other_________________

2.9. Do you use organic fertilizer on teff field?

1. Yes 2. No

2.10. If yes, what kind of organic fertilizer do you use?

1. Green manure2. Animal waste 3. Compos 4. Others, specify______________________

2.11. How many quintals per hectare of organic fertilized do you apply for your teff crop? ____________________________________

2.12. If you are not using organic fertilizer, why?

1. Its bulky to transport 2. Lack of awareness

3. I don’t have animals to prepare it 4. Others, specify___________________________

2.13. Labor use for teff production in 2015/2016 production year based on age category

	Children								Women				Men			
	Male				female											
	11-13		14-16		11-13		14-16		17-50		>50		17-50		>50	
Activities	No	Hrs	No	Hrs	Num	Hrs	No	Hrs	No	Hrs	No	Hrs	No	Hrs	No	Hrs
Plowing 1^{st}																
Plowing 2^{nd}																
Plowing 3^{rd}																
Plowing 4^{th}																
Sowing																
Weeding																

1st																
Weeding 2nd																
Fertilizer application																

3. Output/yield

3.1. How much quintal of teff did you get last year? _____________

4. Type of Livestock owned by the farmer in the production year 2015/2016)

No	Types of animal	Number				Remark
		Owned	Sold	Bought	Number at the end of the year	
1	Oxen					
2	Donkey					
3	Horse					
4	Cow					
5	Sheep					
6	Goats					
7	Heifer					
8	Hen					
9	Chickens					
10	Beehives					

5. Cropping pattern for teff production

5.1. Is your teff plot

1. Gentle 2. Sloppy

5.2. What is the fertility status of your teff plot?

1. High fertility 2. Low fertility

5.3. No of plots owned____________

5.4. What are major annual crops you grow? 1. Bean 2. Teff 3. Pea 4. Teff

5. Wheat 6. Chick pea 7. Guaya

8. Others________________________________

5.5. What type of soil conservation mechanism is employed on your teff plot?

1. Soil Bund		2. Stone Bund

3. Cut of Drain		4. Chek Dam

5. Agro-forestry practices	6. Others___________________________________

5.6. If you have produced teff by rented-in land, how much did you pay?___________

5.7. If you have produced teff in 2008/2009 by sharing land with others, who cover the following expenses? 1. Purchase of seed		3. Purchase of pesticide

5. To hire Oxen power	2. Purchase of fertilizer	4. To hire human labour

5.8. How many quintal of teff was given to the owner of the land?_______________

5.9. When did you sow teff for the production year 2015/2016?

1. Early		2. Lately

6. Income condition of the farmer.

6.1. What is your weekly income from selling of farm products?

Selling of crops(birr)	Selling of crop by products(birr)	Selling of dairy products(birr)	Selling of Honey(birr)	Selling poultry products(birr)	selling of other farm products(birr)

6.2. Do you have any income source other than farming?	a. Yes		b. No

6.3. How much is your average monthly income you gain from off farm activities?______

6.4. What is/are the source of your income?	1. Off-farm activities	2. Renting house or land

3. Pension payment	4. Constant subsidies		5 .Salary/wages

6.others, specify_________________________________

6.5. What is your off farm activity?

1. Tailor	2. Hair making	3. Carpenter	4. Hand craft

5. Pottery	6.Trading	7. Others, specify__________________________

6.6. How many days per month do you spent on off farm activities?_____________

7. Meeting

7.1. How many hours do you spend on kebeke or local meetings in a week?____________

7.2. Who take care of the farming activities while you are participating in these meetings?

1. Only Family members		2. Hired workers and family members

3. The traditional labor arrangements (debo, wnifal, etc) 4. Other specify________________

8. Credit service

8.1. Do you have any sources of credit? 1. Yes 2. No

8.2. If yes, what sources of credit do you have? 1. Formal sources 2. Informal 3. Both

8.3. What are the formal sources of credit institutions?

1. Commercial banks 2. Amhara loan and saving institute
3. NGOs 4. Others specify________________________

8.4. Have you received any borrowing from the formal institutions this year?

1. Yes 2. No

8.5. If yes, what kind of credit does you received?

1. Short term 2. Medium term 3. Long term

8.6. For what purpose do you borrow?

1. For primary basic needs 2. For Medicine
3. For School 4. For input purchase 5. Investment
6. To pay back other loans 7. Other, specify_________________________

8.7. How much money did you received for the current production year? _____________br.

8.8. What is the interest rate? ________________percent

8.9. What are the informal sources of credit?

1. Traders 2. Relatives 3. Friends
4. Iddire 5. Others, specify____________________________________

8.10. For what purpose did you borrow from informal credit sources?

1. For primary basic needs 2. For Medicine 3. For School
4. For input purchase 5. Investment 6. To pay back other loans
7. Other, specify_________________________________

9. What are the major constraints of agricultural production?

1. Weed infestation 2. Crop disease 3. Crop pests
4. Seed shortage 5. Shortage of draft animal 6. Shortage of labor
7. Any other, please specify__________________________________

Name of the enumerator______________________

Signature_____________ Date_____________________